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SEVENTY-FIFTH ANNIVERSARY

OF THE ORGANIZATION OF THE

FRANKLIN INSTITUTE

1824-1899

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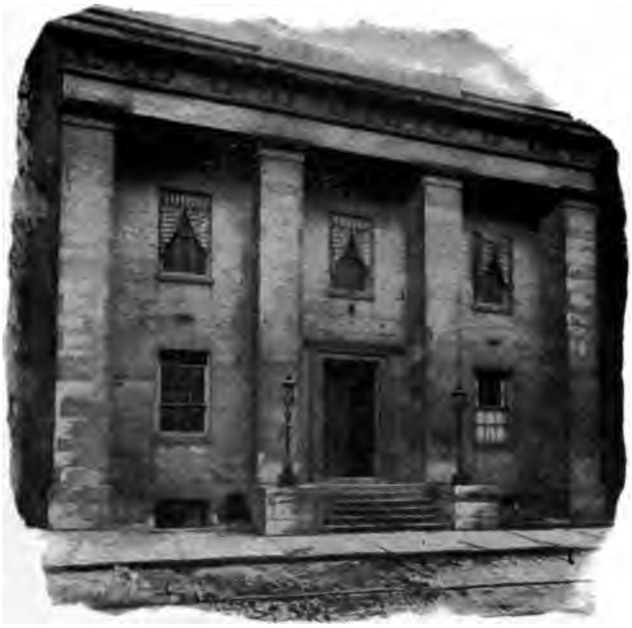

HALL OF THE FRANKLIN INSTITUTE.
Erected 1825.

COMMEMORATIVE EXERCISES

AT THE CELEBRATION OF THE

SEVENTY-FIFTH ANNIVERSARY

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA FOR THE
PROMOTION OF THE MECHANIC ARTS

HELD ON THE EVENINGS OF
OCTOBER 2, 3, 4, 5, 6 AND 7, 1899

IN THE

CONVENTION HALL OF THE NATIONAL EXPORT
EXPOSITION

PHILADELPHIA:
HALL OF THE FRANKLIN INSTITUTE
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INTRODUCTION.

At the annual meeting of the Franklin Institute, held Wednesday, January 18, 1899, the President, on taking the chair, invited the attention of the members assembled to the circumstance that the date of the seventy-fifth anniversary of the foundation of the Institute would fall on February 5, 1899, almost coincidently with the birthday of its illustrious namesake, and suggested the advisability of taking steps to commemorate the event in some formal manner. The President's suggestion was received with much favor, and the subject was referred to the Board of Managers to take such measures as might be deemed proper to carry the President's suggestions into effect. The Board referred the subject to the Committee on Exhibitions, and this Committee made a report to the Board, at its meeting held January 25, 1899, in which the following resolutions were contained:

"*Resolved*, that the Committee recommends to the Board of Managers that formal exercises in celebration of the seventy-fifth anniversary be postponed until the autumn, with the object of commemorating the event in connection with the National Export Exposition, which the Institute contemplates holding at that time in conjunction with the Philadelphia Commercial Museum.

"*Resolved*, that the Secretary be requested to prepare a suitable commemorative announcement of the seventy-fifth anniversary for publication in the February impression of the *Journal*, and to state that formal exercises will be held during the coming autumn; publishing the said impression in more sumptuous form than ordinarily, and with a special cover."

In conformity with the spirit of these resolutions, which were unanimously approved by the Board of Managers, the

February impression of the *Journal* was issued as a "75th Anniversary Number," and with the following references to the anniversary, viz.:

"AN ADDRESS BY THE PRESIDENT, ON THE OCCASION OF THE ANNUAL MEETING OF THE FRANKLIN INSTITUTE, HELD WEDNESDAY, JANUARY 18, 1899.

"*To the Members of the Institute:*

"In opening the proceedings of this annual meeting your attention is invited for a few moments to facts which appeal to your President as entitled to your consideration.

"One hundred and ninety-three years ago yesterday the illustrious Franklin was born, and we may well honor the memory of him whose name was given to the Institute by the founders as the ideal of what should be expected of the membership.

"The public life of Benjamin Franklin stamps him as one of Philadelphia's greatest citizens; nor does his record pale by comparison with those of men who have achieved prominence since Franklin passed away in ripe old age.

"Can we honor his memory better than by maintaining the unselfish good work of the Institute, and by adding to its usefulness? He who carved his way from the printer-boy to the renowned author, scientist, sage and diplomat, early recognized the value of mutual helpfulness by an organization of kindred spirits. Wherever the work of the Franklin Institute is known it honors the name of Benjamin Franklin, and the wider its field of usefulness, the greater honor do we reflect upon that name.

"Within a few days this Institute will have reached the age of seventy-five years, for its organization dates from February 5, 1824, and I would urge upon every member the importance of co-operating in a celebration which will cover the entire seventy-fifth year. Let us maintain a continuous celebration, characterized by concerted effort to advance the usefulness of the Institute, to extend its membership, to encourage its sectional and departmental work, and to secure an endowment such as will relieve your officers from the constant disheartening strain of attempting to carry on a great work with a restricted exchequer.

"A committee having the seventy-fifth anniversary in charge purposes to properly recognize February 5th, but to supplement this recognition by a more formal celebration later in the year, in the hope that by this later date some or all of the above desirable arrangements will be accomplished facts. It is expected that the formal celebration will take place in connection with the exhibition, which it is the present intention of your managers to hold in the approaching autumn, in conjunction with the Philadelphia Commercial Museum.

" Were the Franklin Institute to pass out of existence it would certainly be considered a public calamity, which would be regretted throughout the world. There is, fortunately, no immediate danger of such a calamity, but you are each asked to consider what you would be willing to do to prevent this, and devote your energy in that spirit to its immediate advancement. It is far better to cheer a friend in life than to be willing to shed tears and wear crape at his funeral.

"The additions to the roll of membership, which the Secretary reported to you, and the subscriptions which have been received to the endowment fund, are practical evidences of interest exhibited. The re-arrangement of our priceless library and its protection, and the rehabilitation of our model collection, the increased attendance at our schools, the excellent work being done by sections and committees, all point to an activity which only awaits additions of individual energy to bring to a speedy consummation our most enthusiastic hopes.

"In the two years which have elapsed since you called me to the Presidency we have had much encouragement—encouragement often tempered by the stern necessity of making a limited revenue suffice to cover expenditures already reduced to the lowest practicable basis, but still encouragement, for increased interest by the membership was evidenced by some advance, always in progress or under consideration.

"In view of the prospect before us, may not your President ask the individual co-operation of every member to do something to make our seventy-fifth year of useful work memorable?

"Recalling the conditions which existed seventy-five years ago, we have much to be proud of in the history of our Institute. At the time of its organization, the locomotive and the steamboat were novelties. A journey to Pittsburgh was a greater undertaking in the expenditure of time and physical energy than a trip to-day to Puget Sound.

"The telegraph, telephone, electric railway, sewing machine, and the prevailing systems of lighting, heating and power transmission were all unknown. Scientific agriculture and sanitary science were not yet born.

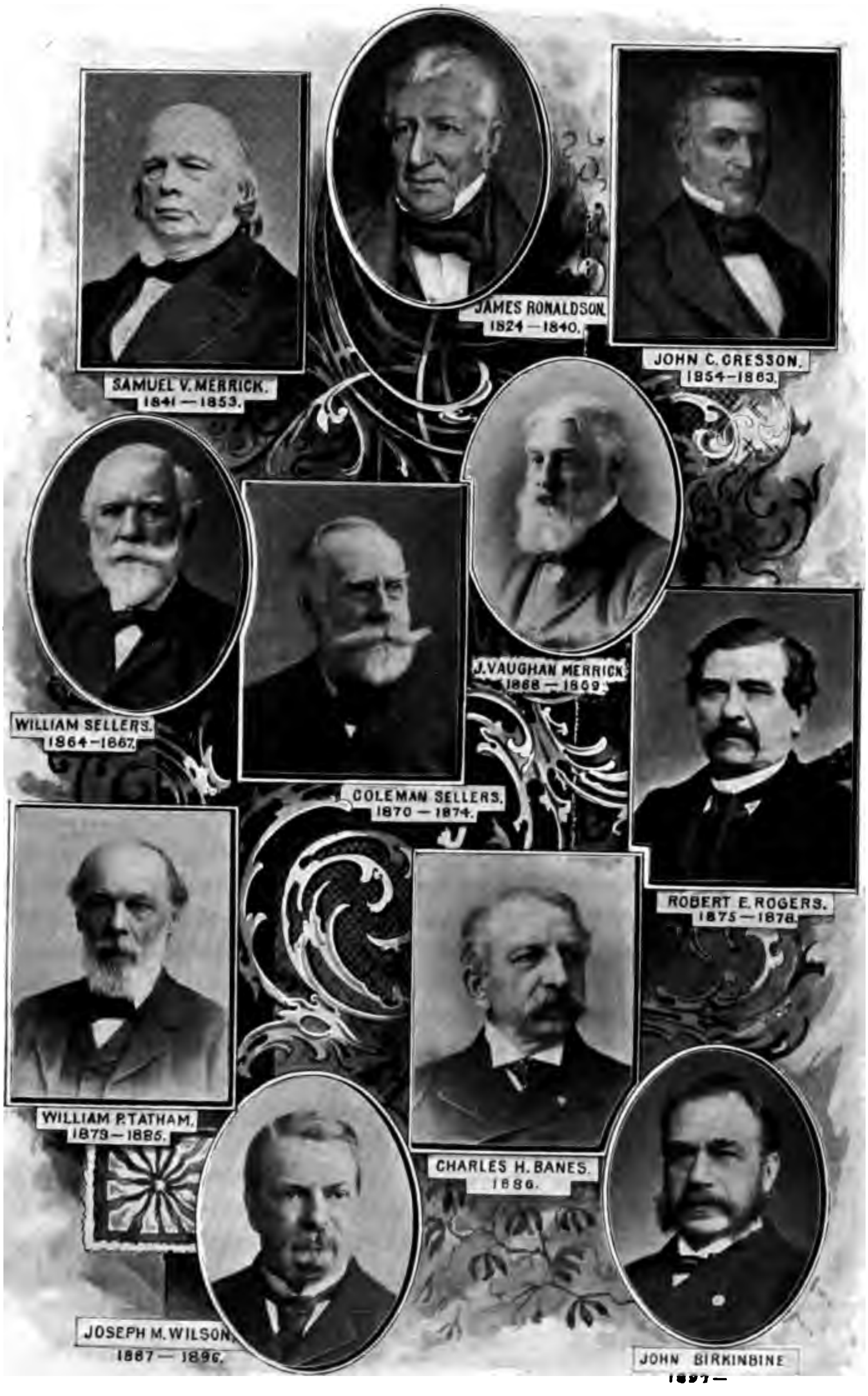
"All the pig iron made in the United States was produced with charcoal, and the annual output of the entire country was below the capacity of one of our modern blast furnaces.

"These comments are only suggestive of the numerous advances which the *Journal of the Franklin Institute* has chronicled, and which have resulted in the present state of scientific and commercial progress. Each one can add to this imperfect list.

"Many of the discoveries and inventions which will suggest themselves were first brought to the attention of the world in this venerable building, and for quite a number our Committee of Science and Arts has awarded medals.

"Recalling an honorable history and bearing an honored name, let us unite our energies to maintain the position which we are proud to know is accorded to the Institute among the learned societies of the world, and pave the way for a future which will prove that the Franklin Institute has been, is, and will continue to be, in touch with every advance, not in the mechanic arts merely, but in all the practical applications of science to the arts that benefit mankind.

JOHN BIRKINBINE,
President."


SAMUEL V. MERRICK. 1841 — 1853.
JAMES RONALDSON. 1824 — 1840.
JOHN C. CRESSON. 1854—1863.
WILLIAM SELLERS. 1864—1867.
J. VAUGHAN MERRICK. 1868 — 1869.
COLEMAN SELLERS. 1870 — 1874.
ROBERT E. ROGERS. 1875—1878.
WILLIAM P. TATHAM. 1879—1885.
CHARLES H. BANES. 1886.
JOSEPH M. WILSON. 1887— 1896.
JOHN BIRKINBINE 1897—

Presidents of the Franklin Institute,
1824–1900.

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At the same meeting, the Committee reported that it had extended an invitation to the Rev. Dr. Henry C. McCook, to preach a memorial sermon on Sunday, February 5, 1899, the seventy-fifth birthday of the Franklin Institute. Dr. McCook courteously accepted the invitation. The subject of the sermon, which was delivered in the Tabernacle Presbyterian Church, Thirty-seventh and Chestnut Streets, was "The Divine Architect," and is published in full in connection with this volume. A large number of the officers, managers and members listened to the speaker, to whom the Board of Managers, at its stated meeting held February 8, 1899, passed a unanimous vote of thanks.

As an interesting contribution to the history of the Institute in connection with the organization and holding of the "National Export Exposition," and the celebration of the seventy-fifth anniversary of the Franklin Institute, the following abstract from the minutes of the stated meeting of the Institute held September 20, 1899, is appended, viz.:

ABSTRACT OF REPORT OF THE COMMITTEE ON EXHIBITIONS.

Your Committee presents the following report of its work and of those associated with it, in preparing for the National Export Exposition of 1899. The Executive Committee of the National Export Exposition consists of representatives of the Exposition Association, an organization duly chartered to carry on an exposition, the Commercial Museums and the Franklin Institute. This Executive Committee was divided into numerous sub-committees, who were to do the actual work of preparing for the exposition. These sub-committees are as follows:

Grounds and Buildings; Rules and Regulations; Amusements, Attractions and Concessions; Law; Publicity; Finance, Admittance and Insurance; Classification and Space. * * * *

Owing to the fact that the majority of the members of the Executive Committee were active business men, it was deemed advisable to have as few meetings as possible for the proper conduct of the work. The detail work was done by the several sub-committees above noted.

The reports of the sub-committees were made directly to the Board of Directors of the exposition as the responsible head.

In all organizations of this kind some few members do the actual work, and the members representing the Franklin Institute have attended faithfully the meetings of the several sub-committees; in fact, we have always had a fair representation and oftentimes a majority of the members present, and the Board of Directors has invariably approved the work. We are happy to say the exposition was opened, on the 14th of September, under the most favorable conditions. * * * *

THE SEVENTY-FIFTH ANNIVERSARY.—In reference to the seventy-fifth anniversary, elaborate preparations have been made to celebrate the occasion during the first week of October, and it is hoped that the members of the Institute will aid the Committee by their support and attendance.

A program has been arranged giving each section of the Institute one evening, and there will be a general Institute meeting on the closing night, Saturday, October 7th, at which Dr. Robert H. Thurston and Rear-Admiral Melville, Engineer-in-Chief of the U. S. Navy, will make the addresses.

Invitations are now being engraved and programs printed. These invitations and programs will be received by each member within a week.

A Franklin Institute reception room has been provided on the second floor of the north pavilion of the Exposition building, directly over the main entrance. An employé will be in attendance at this reception room during the exposition, and it will be used as a reading and reception room for the members and their friends. We hope that the members will avail themselves of this room.

The details in reference to the awards have not yet been worked out, but this matter has been placed entirely in the hands of the Franklin Institute. * * * *

HENRY HOWSON,
Chairman Committee on Exhibitions.

PHILADELPHIA, September 20, 1899.

The Secretary called attention to the notable circumstance that the Honorable Frederick Fraley, one of Philadelphia's oldest and most distinguished citizens, was the sole survivor of the founders of the Institute, and urged the propriety of taking special action in connection therewith; whereupon the following resolution was adopted unanimously:

"The members of the Franklin Institute, in stated meeting assembled, and engaged in the consideration of plans for the celebration of the Seventy-fifth Anniversary of the society, by unanimous vote have instructed their President and Secretary, in their behalf, to convey to the Honorable Frederick Fraley, their cordial felicitations upon the circumstance that he, of all his colleagues, who attended the historic meeting in the County Court House, Sixth and Chestnut Streets, on February 5, 1824, to inaugurate the Franklin Institute, still survives, and to express their earnest hope and expectation that he will be able to honor the occasion of the closing ceremonies on 'Institute Day,' Saturday, October 7th, or any of the ceremonies of Institute week, in the Convention Hall of the National Export Exposition, with his presence and participation."

FREDERICK FRALEY.

PROGRAM OF THE SEVENTY-FIFTH ANNIVERSARY OF THE FRANKLIN INSTITUTE.

The celebration of the Seventy-fifth Anniversary of the Institute should properly have taken place on February 5, 1899. In view, however, of the circumstance that the Institute would probably participate in conducting the National Export Exposition in the autumn, it was decided by the Board of Managers to postpone the event and arrange to have the celebration take place during the exhibition, as part of the numerous public functions to be held in connection therewith.

In accordance with this decision, it has been arranged to hold in the Convention Hall of the Exposition, during the week beginning Monday, October 2d, and ending Saturday, October 7th, a series of special anniversary meetings under the direction of the several sections of the Institute, to follow one another on successive evenings, and to be concluded by a special meeting of the Institute. At these meetings it has been arranged that addresses appropriate to the occasion shall be delivered by distinguished invited guests and members of the Institute. The series of meetings and addresses arranged is as follows:

MONDAY, OCTOBER 2D, 8 P.M. CHEMICAL SECTION.

Dr. Joseph W. Richards, Bethlehem, Pa., President of the Section. "Introductory Address."

Prof. Harvey W. Wiley, Washington, D. C. "The Progress of Chemistry as Applied to the Arts."

Dr. Charles F. Himes, Carlisle, Pa. "The Making of Photography." (Photographic and Microscopic Branch.)

TUESDAY, OCTOBER 3D, 8 P.M. ELECTRICAL SECTION.

Prof. George A. Hoadley, Swarthmore, Pa., President of the Section. "Introductory Address."

Dr. Edwin J. Houston, Philadelphia, Pa. "The Seventy-fifth Anniversary of the Franklin Institute from an Electrical Standpoint."

Mr. Ralph W. Pope, New York. "The Influence of Technical Societies in Promoting the Electrical Arts."

WEDNESDAY, OCTOBER 4TH, 8 P.M. MINING AND METALLURGICAL SECTION.

Mr. James Christie, Philadelphia, Pa., President of the Section. "Introductory Address."

Mr. Charles Kirchhoff, New York. "Three-quarters of a Century's Progress in Mining and Metallurgy."

Mr. John Fritz, Bethlehem, Pa. "The Development of Iron Manufacture in the past Seventy-five Years."

THURSDAY, OCTOBER 5TH, 8 P.M. MECHANICAL AND ENGINEERING SECTION.

Mr. Wilfred Lewis, Philadelphia, Pa., President of the Section. "Introductory Address."

Dr. Coleman Sellers, Philadelphia, Pa. "The Progress of the Mechanical Arts in three-quarters of a Century."

FRIDAY, OCTOBER 6TH, 8 P.M. PHYSICAL AND ASTRONOMICAL SECTION.

Dr. A. E. Kennelly, Philadelphia, Pa., President of the Section. "Introductory Address."

Dr. T. C. Mendenhall, Worcester, Mass. "Some Notable Contributions of American Physicists during the last three-quarters of a Century."

SATURDAY, OCTOBER 7TH, 8 P.M. "INSTITUTE DAY."

Dr. Robert H. Thurston, Ithaca, N. Y. "The Evolution of Technical Education and its Progress during the past Seventy-five Years."

Rear-Admiral Geo. W. Melville, Engineer-in-Chief, U. S. N. "The Modern Warship as Combining in itself the highest Results of Skill, Ingenuity and Scientific Knowledge."

Mr. John Birkinbine, Philadelphia, Pa., President of the Institute. "Closing Address."

This program was followed literally. The commemorative meetings were largely attended by the members and friends of the Institute. The inaugural meeting on Monday evening, October 2d, 1899, was opened by an informal and cordial address of welcome by Dr. W. P. Wilson, Director-General of the National Export Exposition.

The addresses delivered at the series of meetings follow in regular order.

W. H. W.

Opening Address.

By John Birkinbine,
President of the Franklin Institute.

Members of the Franklin Institute, Ladies and Gentlemen:

Who can estimate the work which the Franklin Institute has accomplished in seventy-five years of activity, or gauge the influences traceable directly or indirectly to the efforts of its members for the advancement of the Mechanic Arts? The more the subject is studied, the wider appears the range which the Institute's work has covered, for even a cursory examination of the 148 volumes which are comprised in the impressions of the *Franklin Journal* and the *Journal of the Franklin Institute* shows how generously all branches of applied sciences have been discussed at its meetings.

This most valuable collection of data does not, however, include the detailed discussion or the personal exchange of opinions which followed the presentation of the papers, lectures or investigations, many of which in all probability started lines of thought resulting in the invention of advanced methods, improved tools, appliances and machinery.

The excellent record of the Committee on Science and the Arts, and its predecessor, the Committee on Inventions, also covers only the formal findings of this body, and does not present the details of the investigations on which these findings were based—details which suggested to inventors a wider field than was contemplated or which corrected erroneous ideas.

Possibly no more useful service was rendered than in refusals of these Committees to grant awards or medals, for by so doing the inventor was dissuaded from proceeding with what would have brought only discouragement and disaster, or was directed in a course concerning the importance of which he had little or no previous conception. The conscientious investigation by disinterested men of a multitude of projects, many of them crude and incomplete, has been one of the most valued specialties of the work of the Franklin Institute.

We do not claim that all that has been done or said in the lecture room, or in committee sessions, has been mechanically or scientifically orthodox (if such a term may be used), for in seventy-five years there have been numerous opportunities for charlatans, promoters, or enthusiasts whose "little learning made them mad," to present views which were at variance with accepted facts, and often with natural possibilities. But we know that within the walls of our venerable home many pseudo-scientific hobbies have been overturned and more than one pretender or false prophet has met discomfiture. We also have excellent ground for the assertion that few, if any, organizations having similar objects, have clearer records or greater reason for pride in a review of what was attempted, and what has been accomplished.

While this may appear as self-glorification, it is only such in so far as the Franklin Institute is considered as an organization, for while the present membership is equally active and faithful, our reference is largely to the work of those who have passed from their earthly labors, and whose names are only recognized by their place in musty roll books, but the record of their labor is preserved in the volumes of the *Journal*, which embody the history of the Franklin Institute.

Those who to-day watch the eager listeners in our lecture rooms as they absorb the views of a lecturer or critically follow the exposition of a novel process or improved machine, may well remember that for three-quarters of a century similar scenes could have been witnessed.

Turning to a list of those who have stood before audiences in the Franklin Institute building, either to lecture or to explain process, invention or experiment, there is just cause for pride that the array of notable men is so imposing. An attempt to trace the influence which the speakers exerted upon the audiences or to the far greater number who were reached by their words when printed, is unnecessary to demonstrate the useful, helpful work of the Institute.

We may, therefore, enter upon the celebration of the seventy-fifth anniversary of the Franklin Institute, proud of the work which it has accomplished, of the work which it is doing, and confident that its efforts will not relax. The scriptures tell us that "a good name is rather to be chosen than great riches." We know that the Franklin Institute has not wealth, but realize that it has a good name, not in Philadelphia only, nor confined to Pennsylvania, nor even to the United States. It stands well to the fore among the learned societies of the world, and no other technical American publication has a wider circulation in European libraries, or is held in higher esteem than its *Journal*.

The insignia of membership in the Franklin Institute means more in foreign countries than in our own. Let each one of us do his or her part to preserve the honor of the organization, that its badge may continue to be recognized as a symbol of membership in an institute, honored for what it has accomplished and for what it is doing for the promotion of manufactures and the useful arts.

HENRY MORTON, 1864–69.

JACOB B. KNIGHT, 1875–78.

ISAAC NORRIS, 1878–81.

WILLIAM H. WAHL, 1870–74, 1882–

SECRETARIES OF THE FRANKLIN INSTITUTE,
1864–1900.

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Henry Morton, 1864–69.

Jacob B. Knight, 1875–78.

Isaac Norris, 1878-81.

William H. Wahl, 1870–74, 1882–

Secretaries of the Franklin Institute,
1864–1900.

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Anniversary Meeting of the Chemical Section.

INTRODUCTORY ADDRESS.

BY DR. JOSEPH W. RICHARDS,
President of the Section.

Members of the Chemical Section, Ladies and Gentlemen:

The Chemical Section of the Institute, being the oldest of its sections, has been charged with the pleasant duty of inaugurating the proceedings of this commemorative week.

JOSEPH W. RICHARDS.

Chemical science has always been prominently represented among the Institute's membership. The organizer of the Institute, Samuel V. Merrick, was himself a practical mechanician, but he had as his co-worker William H. Keating, Professor of Chemistry at the University of Pennsylvania, and these two sent out together the first call for a preliminary meeting. Thus mechanics and chemistry conjointly presided at the birth of the Institute, fittingly typical of its future sphere of activity.

As soon as the Institute was officially organized, Professor Keating was appointed its professor of chemistry, thus from the start recognizing and confirming the prominent relation which chemical science was meant to sustain towards the work and objects of the Institute.

The duties of the Institute's professor of chemistry appear to have been the delivery of a graded course of lectures to students and apprentices, the arranging of lectures by prominent specialists in chemistry, the editing of chemical communications offered to the Institute for reading and publication, giving criticism and expert advice to the Committee on Inventions and Discoveries, and acting as conservator of the chemical apparatus and equipment of the Institute. With the establishment of the Philadelphia High School, and the general development of the higher educational facilities in and around this city, the graded course of lectures became superfluous, and, on the organization later of the Chemical Section, the functions of the professor of chemistry have been shifted to it and its various committees.

In 1881, the chemical work of the Institute was of sufficient importance to warrant the formation of a distinct section for the discussion of the particular problems of pure and applied chemistry. It was true then, as now, that at the general meetings of the Institute only questions of general scientific interest can be brought forward, while problems of interest only to professional chemists, or capable of being understood and discussed only by such, were necessarily excluded from the program. The chief advantage of the formation of the section was that it enabled the chemists to come together at their own meetings, to discuss without the distractions of a general assemblage the higher problems of chemical science and industry. The result was the immediate enlargement of the sphere of the Institute's activity.

This principle of the subdivision of the Institute's work has been so fruitful of results that the example thus set has been followed by the formation of no less than four other sections and one sub-section. Specialization is to art and science what division of labor is to industry; it is the modern method of setting every one to work and reaching large results. The creation of each new section has been a distinct gain to the Institute, stimulating individual effort in the directions thus specialized and reacting on the rest of the membership by the general increase of interest in the Institute's work.

This year has seen the principle extended to a still greater degree, the organization of the Photographic and Microscopic Branch of our Section having been such a success as to amply justify its formation. As you may see from the program, the latter half of this evening's proceedings are in their hands. The creation of new sections as rapidly as circumstances will justify their formation is therefore *the* characteristic of the Institute's present policy, and the ideal condition of the Institute's plan will only be attained when every prominent branch of science, art and industry has its appropriate section, and every member of the Institute, whatever his specialty, can be thus enrolled among congenial co-workers. The perfected plan will result in a republic of free and independent sections under the general government of the parent Institute.

Previous to 1881, nearly a hundred original communications on chemical subjects had appeared in the *Journal* of the Institute. Since then, the Chemical Section has held 174 meetings and listened to 215 lectures or papers. A free discussion has always been a characteristic of the meetings. The subjects treated have ranged from the most prosaic details of applied chemistry to the most refined speculations of pure chemistry.

One striking characteristic of the illustrious Franklin was undoubtedly his intensely practical as well as philosophic mind. The Institute which so worthily bears his name, true to its great prototype, has always stood for the happy combination of theory and practice, the union of pure and applied science. But, in no art or industry is the interdependence of theory and practice, the coördination of the laboratory and the workshop, more intimate than in chemistry. The atmosphere of the Institute has, therefore, been particularly favorable to the development of the chemical arts. Here, in its halls, have met students and workmen, teachers and business men, thinkers and doers; and sitting side by side, each has learnt from the other and all have been mutually benefited.

Aside from this characteristically democratic tone of the meetings, members of the section have been peculiarly favored in several other respects, such that probably no other chemical society in America offers its members equal advantages. Briefly referred to, they are as follows:

(1) The use of the Institute's library and reading-room: The library is particularly rich in old and rare works on chemistry. One of our recent lecturers, coming from Washington to lecture on the history of pneumatic chemistry, expressed himself publicly as surprised and delighted at the wealth of old chemical literature on our shelves, some of the works being so rare that, although familiar with their names, he had never until that time been able actually to see them. Besides these, the wealth of journal literature, more useful than any other to the chemist, is extraordinary. Among the 400 journals on file in the library, most of them complete, are fourteen concerned exclusively with chemistry, and no less than eighty-three partially. The value of complete sets of American, British, French, Swiss and German patent literature also merits that they be mentioned in even the briefest allusion to the library. Recent works on chemistry are only fairly well represented, but a committee of the section is at present busily engaged in supplying this deficiency. Taken all around, it is certainly the equal, and possibly the superior, of any other chemical library in America.

(2) The frequent lectures on live topics by distinguished specialists: The lecture list of the Institute has been particularly rich in chemical lectures of high grade by specialists in their profession. The privileges of members in this regard during the last few years have been exceptional. Time does not permit any further particularization; the presence with us to-night of our distinguished colleague from Washington, to add interest to our proceedings by an address, will illustrate and emphasize anew this very valuable feature of the section's work.

(3) Immediate and effective publication: The *Journal* of the Institute is unsurpassed among scientific journals for giving immediate and world-wide publicity to its contributions. Passing out to several thousand members and subscribers, finding its place on the files of all scientific libraries, and, particularly, by means of its 400 exchanges entering at once into the hands of scientific editors everywhere, to be quoted, translated, extracted from, discussed—

its communications are assured, in the most effective manner, immediate publicity in the scientific world.

(4) The use, at present, of a considerable stock of chemical apparatus; and, prospectively, of a laboratory to use it in: Thanks to the liberality of several members of the Institute, the store of chemical glassware, porcelain, balances, microscopes and photographic apparatus now in the possession of the section is large and useful. Nearly $2,000 worth of such material recently came to us from the estate of Dr. M. Carey Lea alone. This apparatus is primarily for use in illustrating lectures and papers at the Institute, but recent action of the section has placed it at the disposal of any of the members, to be loaned out under suitable regulations.

It is just here that there is a splendid opportunity for extending the usefulness of the section. The apparatus already owned by it would equip several rooms for research work in chemistry, metallurgy, mineralogy, photography, microscopy and allied fields. Such a laboratory would be at the disposal of committees appointed to investigate special questions, or allow any member to translate his ideas and suggestions into experiments. It was a saying of Deville, that "It is not necessary to theorize if you can make the experiment," and who can tell how many bright ideas, valuable suggestions, pregnant thoughts have been called into being at our meetings, and yet have failed of fruition because the member thinking them had not the facilities for making the light-bringing experiment. Great ideas are probably as rare as great geniuses, but it is our right and duty to nurture them wherever there is a possibility of their developing. May we not express the hope that in the near future the idea of such laboratories may materialize, to the great advantage of the membership and increase of usefulness to the Institute?

The Chemical Section is thus seen to be prodigal in the advantages it offers its members. To the Institute itself it is of service in providing a definite organization for the handling of a definite part of its business. The investigation of chemical questions, the care of the chemical equipment of the Institute, the oversight of the chemical division of the library, the entertainment of distinguished chemists, fall naturally to its committees or members. Granted, however, that a well-arranged laboratory is added to our resources, for which we already possess the equipment, and there may develop a public function or relation of the section to the community which would be by no means unimportant. There are many questions of importance to the community which committees of the section, working in its own laboratory, would be able to solve without fear or favor. Such important matters might be an examination of the municipal water supply, tests of the adulterations in foods, fixing of standards of purity of foods, examination of the material proposed for public monuments, the effectiveness of methods of disposing of sewage, etc. There are, of course, officials already charged with the nominal fulfilment of such duties, but the committees mentioned, rendering unbiased decisions solely for the benefit of the community or commonwealth, would constitute a court of last resort on all such debated and unsettled cases, which would prove of great public value.

We felicitate the Institute and the Chemical Section on the work already achieved. We thank our members for their unselfish devotion, and call on those present to sustain the high standard which has been attained.

We extend a hearty greeting to all our friends who are joining in our celebration, and particularly to visitors and the speakers from a distance, who, at the expense of time and effort, have thus shown their interest in our work.

It is with satisfaction and pleasure that I now introduce the first speaker of the evening, a distinguished colleague, an honorary member of the Institute, ex-President of the American Chemical Society, and Chief Chemist of the Department of Agriculture, Dr. H. W. Wiley, of Washington, the subject of whose address is "The Relation of Chemistry to the Advancement of the Arts."

THE RELATION OF CHEMISTRY TO THE ADVANCEMENT OF THE ARTS.

BY HARVEY W. WILEY,
Honorary Member of the Institute, Chief Chemist to the U. S. Department of Agriculture, Washington, D. C.

The founding of the Franklin Institute, three-quarters of a century ago, marked the inception of a new relationship in this country between science and the useful arts. In the foundations here laid were provided the means whereby the generations which were to come, who would be deprived of the advantages of academic and technical training in the great institutions of the country, might yet come into touch with science and feel the impetus of its practical application. The provisions here made were not intended for the millionaire, or even the well-to-do citizen, but were planned for the benefit of the artisan, the laborer and the workingman whose intelligence enables them to comprehend the true meaning of science and whose tastes and industry incline them to take advantage of it.

HARVEY W. WILEY.

The Franklin Institute was the forerunner of many institutions of similar import which have since been established in the different parts of the country. Among these may be mentioned the Cooper Institute, of New York, the Pratt Institute, of Brooklyn, the Lowell Institute, of Boston, and the Armour Institute, of Chicago. These great centers for the distribution of practical knowledge are all established upon the general principles which guided the founders of the Franklin Institute in the great work which they have accomplished.

Science, in order to become useful to man, must be vivified by coming into contact with man's industries. It is a misnomer to apply the word "pure" to a science which is latent, and yet we constantly see in the text-books and hear in the lecture-room the expression "pure sciences," meaning thereby research for truths not intended for immediate practical application. I would detract nothing from the dignity of research, nor from the glory and honor of the achievements in the realms of abstract investigation, but I do protest against discrimination which is made or which may be made, in the public judgment, in the use of terms which, to the general reader, may convey a wrong impression. If one branch of science is pure, there is an inclination to believe that another branch is less pure, or is even impure. Whereas, in point of fact, all branches of scientific investigation and application occupy similar positions in their claims upon the attention and the guidance of humanity.

The severely practical man thinks that there is no justification in delving for knowledge for which there is no immediate practical application in view. He should remember that any addition to human knowledge is finally not without some application to human progress, and, however abstract and impractical the results of an investigation may seem, if they afford new light and new knowledge, they will, some day or other, justify the time and the labor which have been consumed in obtaining them.

On the other hand, the devotees of pure research sometimes admit no justification of practical application, and view with contempt the efforts of those who seek to apply for immediate use the great principles underlying scientific investigation. These, however, have some claim for recognition also, and stand upon the same foundation of truth as the scientific anchorite.

If we look casually over the great constructive arts and industries of the world, we find that they are all practically based upon three great sciences, namely, mechanics, physics and chemistry, and these three sciences are the fundamental ones underlying the great activity of the Franklin Institute. To one who has never had his attention called to this subject, a surprise is in store if he considers carefully the above statement. Whatever be the industry to which his attention is called, he will find that in its inception, its development and its attainments the three great sciences mentioned have played a most prominent part.

Other speakers will call your attention, doubtless, during this anniversary week, to the relations which mechanics and physics bear to the arts. I am invited to-night to say something of the relationship which the science of chemistry bears to the progress of the useful arts. In doing this I disclaim at the outset any intention to minimize the influence which any other science, and especially those mentioned above, may have had upon the development of the industrial life which at present dominates the progress of humanity. While, of course, from my point of view, to-night, chemistry is the chief factor of this dominating influence, you will have this progress exhibited to you from other standpoints before these anniversary exercises are concluded.

During the short time allowed to this address I shall not endeavor to go into elaborate details in regard to any one of the useful arts, but shall rather attempt, in a general way only, to establish clearly the influence which the science of chemistry has had upon industrial development; in other words, to elaborate, at least in outline, the philosophy of industrial development in its relations to chemistry.

Man, in the exercise of his activities, has at his command the raw materials which nature affords, or which he himself produces, and the natural forces which may be directed in the elaboration and utilization of these materials. The changes which matter undergoes in its transformations are, as is well known, twofold, namely, mass changes and molecular changes.

If, for instance, a block of iron ore be transported from Lake Superior to Pittsburgh, we have change of mass or mass motion. If, after it is left at Pittsburgh, the ore is placed in a furnace and reduced to the metallic state, we have molecular motion, in which the character, properties and appearance of the mineral are radically changed.

Now, in all the industries, no matter what they may be, these changes of the molecular nature of substances are the principal ones to be considered. In the fundamental one of all, namely, agriculture, we see the most striking illustration of this principle. The scientific agriculturist has at his disposal certain elements in the soil and in fertilizing materials, as well as the natural forces, which, aggregated, may be designated as meteorology and climatology; in other words, the forces of water, heat, light and air, in the exercise of his art. His purpose is to transform the elements of plant food into organic products suitable for the nourishment of life and for other useful objects. Every one of these changes is of a chemical nature; in fact, in no industry has the fundamental basis of chemistry been so generally recognized as in the science of agriculture.

In the development of agricultural industry during the past fifty years, there have been founded in all parts of the world agricultural experiment stations, for the study of the principles underlying scientific agriculture. A glance at the names of the directors of these stations will show more strikingly than any other illustration the dominant influence of chemical science. I lately had occasion to look over the names of the directors of the agricultural experiment stations of Germany. I found that more than 70 per cent. of the men who are in charge of scientific investigation, from an agricultural point of view, in the German Empire, are professional chemists.

In our own country, out of fifty agricultural experiment stations now in existence, twenty are directed by professional chemists. But the dominant influence of chemistry in the agricultural stations of this country is not measured by the relative number of professionally trained chemists who are directors of the stations alone, but by the importance of the work done by these stations as compared with that performed by the others. If one well posted in the matter were asked to name the fifteen most successful agricultural experiment station directors of the United States, I am sure almost every one whose name would appear in the list would be one of the twenty mentioned above.

A much larger proportion of the total number of directors, doubtless, would be found in the chemical profession were it not a very prevalent custom in this country to make the president of the agricultural college also the director of the station, which is usually located at the same place and is under the same board of managers.

Another fact which emphasizes more than those already mentioned the dominant influence of chemical science in the station work is that, of the remaining thirty directors, cited above, very few have had professional scientific training of any kind. In the hasty organization of the agricultural experiment stations of the United States it was found impossible to get professionally trained experts in all cases for directors. In many instances the men chosen had no other preparation than the ordinary college course. Among the station directors, therefore, there is no science which has any prominence whatever, in the way of professional application, aside from chemistry. As an illustration of this, it is only necessary to attempt to name the directors who have been trained as engineers, physicists, botanists, entomologists, geologists or in any of the other well-known sciences. It is probable that there may be one representative of some one of these among the various station directors, but of some sciences there cannot be found even one representative. It may be stated broadly, therefore, allowing for an occasional exception, that chemistry is the one science which is professionally represented in the directorate of the experiment stations of the United States.

In point of fact, the agricultural experiment stations of the United States which have been directed by chemists have taken such a leading position in the development of agricultural science as to practically monopolize all those investigations which have been most useful to agriculture throughout the country.

Among the working forces also of the experiment stations, chemists predominate. There are three times as many chemists employed in the stations as there are those engaged in other professional scientific work. For instance, the number of chemists employed in the agricultural experiment stations of the United States is 157, while the total number of botanists is fifty, and the total number of entomologists is forty-two. Furthermore, the number of other professional scientists employed in the stations is still less even than the number of botanists and entomologists. The number of chemists, therefore, engaged in chemical work in connection with the agricultural stations of the United States is considerably greater than that of *all* others working along other scientific lines.*

The dominant influence of chemical science, however, does not stop with those studies which treat of the processes whereby the inorganic materials of the earth's crust, air and water, enter into organic forms suitable for the sustenance of organic life. Directly following the study of these products is that great class of agricultural chemical technics, whereby the raw materials produced in the fields, gardens and orchards are converted into other products. There is no branch of agricultural chemical technology which is not based upon chemistry and its applications. I need only enumerate the great industries of this class to emphasize my statement. Among these may be mentioned tanning, brewing, distilling, starch manufacture, glucose manufacture, sugar manufacture, wine making and many other similar industries. In each one of these great technical arts, chemistry is the fundamental science whose applications bring success. The time is passed when it is possible to conduct any of these great industries without the direct or indirect aid of chemistry. In many cases a professional chemist is the director or manager of the factory. This is almost universally true of the glucose and sugar manufactories of the world. In the brewing industry the work of the chemist is of no less importance, although his managerial participation in the work is more limited; and so with all the other industries of this nature.

A cursory study of the processes employed in these great technical operations will show that almost all the progress which has ever been made therein has been due to chemical research. The changes which raw materials undergo in manufacture are almost wholly of a chemical nature. A proper understanding of these changes is the first step necessary to their most economical and perfect operation; therefore, if at the present time all participation of chemical knowledge and its applications in the great technical industries were to be entirely suspended, there would be no further progress in these lines of work, and at the end of 100 years instead of an advance, we would find a retrogression in them all.

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*If a census were made of the European stations, there is little doubt that the result would be exactly similar.

I have spoken of agriculture as the dominant industry to which chemistry is particularly allied. I did not do this because I wish to minimize the importance of the other industrial arts with which chemistry is vitally connected, nor because agricultural industries are the ones with which my life-work has been most intimately associated, but because I regard agriculture as the most fundamental art and industry of them all, since without it all the others are impossible. The poorly-fed and poorly-clad nation is the one in which no great industry can thrive. Advancement of a nation in wealth, in power and in influence is conditioned first of all by its food supply; in other words, the development of a nation or of an individual is largely a question of nutrition.

Further than this, the area of the world suitable for agriculture is a fixed one. Man cannot create as well as utilize the fields. First of all, of course, the most fertile and most promising regions are occupied. Little by little the areas less adapted to agriculture are occupied and subdued. When the prairies are exploited the forests are attacked, and when the areas freely watered by the rains of heaven are exhausted, man seeks fresh fields in the arid or semiarid regions. The floods are dammed and stored up for future use, and the interior of the earth is tapped to secure the supplies of water which flow in the dark secret channels of the subterranean world. But when all these possible areas are occupied, there will no longer be any increasing acreage for the production of human food. On the other hand, we see the population of the earth rapidly increasing under the impetus which the achievements of science have given to man's powers over nature. It is evident, therefore, that the food of the future must be provided by increasing the fertility of the arable soil of the world. Chemistry is the one science connected with agriculture which teaches man to produce his crops and then leave his fields more fertile than they were before. Hence, to chemistry alone the future world must look for its food supplies. And do you ask, will chemistry be sufficient to meet the demands which the future will make upon it in this direction? My answer must be an assuring one. Under the favoring influence of applied agricultural chemistry the fields of the world are increasing their yields. In the north of France the yield per acre of wheat at the present time is nearly double what it was fifty years ago, and this is but one of the instances of what scientific agriculture has been able to do.

Unfortunately, in our own country we have, up to the present time, had little occasion to appeal to agricultural science for help. The fertility of our soils and their vast area have rendered the farmer, to a certain degree, independent of scientific help. But the time has now come when the most productive part of our country is fully occupied. Already we begin to feel the stress of the agricultural population bearing upon the borders of the arid regions, and asking national and State aid for the development of water supplies and the recovery of the arid lands. The level forests and the arable prairies of the humid regions have been fully occupied. In fact, so many of the trees have been felled to make place for the plow as to excite the concern of thoughtful men in regard to the preservation of our forest domain. The time has, therefore, now come when we must look to an increasing yield rather than to an increasing area for the greater food supplies which the future will demand. I, for one, have no doubt of the ability of chemical science to respond to the call which will be made upon it to supply the coming generations, numerous as they may be, with abundant stores of food.

I have spoken thus at length of the intimate relation which chemistry bears to the art of agriculture, not alone because it is the particular theme assigned to me, nor because it is the one which most nearly interests me, but because I believe it to be a question of the most vital importance to our whole people. I would not, however, minimize the importance of the relations of chemistry to the other industrial arts which go to make up the prosperity, the wealth and the glory of our country.

The organization of this great exposition, the first one of its kind ever held, shows you how, in the applied sciences and technical skill of the United States, we are reaching out for the markets of the world. In every one of the technical arts represented in this great exposition chemistry forms an essential part. If I call your attention to metallurgy, which is purely a chemical science, there is, perhaps, no boon, after the production of food, more grateful to mankind than the cheapening of the metals which are necessary to the various industrial arts. Chemical science, combined with mechanical skill, has accomplished this most desired result. Iron and steel not only form the framework of our great buildings which push their attics skywards in our large cities, but I may say that they are the framework and skeleton around which our wonderful nineteenth century has been built. They have as intimate a relation to the progress of mankind as they have to the support of the walls of the building of which they are the frame. By chemical processes many of the ores of gold and silver, which a few years ago were so refractory as not to be fit for use, now yield abundant supplies of the precious metals. The supply of gold has become so great that it has become the money standard of the whole world, with a few insignificant exceptions, and, even in those countries where it is not the adopted standard, we already see signs of a movement to make it so. Thus, from the metallurgy of this one metal alone, we see that the whole commerce of the world is now based upon a single standard, insuring a degee of stability which has never before been obtained in commercial transactions.

Owing to chemical science another metal also, formerly costly and impossible to use in the arts, has become a common article of commerce. Aluminum, of course, is still in its infancy, and yet we see already that it is destined, both by itself and in combination with other metals, to be of great usefulness to mankind. By reason of its lightness, its toughness and its durability a future day will see it displace the cheaper metals, such as steel, in many structures where steel is now alone employed. I am not here, however, to prophesy the future, but simply to indicate what chemistry has already done up to the present day.

It is unnecessary to multiply instances illustrative of the vital part which chemistry plays in the science of metallurgy, or of the dominant influence which metallurgy has had upon the progress of civilization. Of all the missionaries who have been sent out by devoted men to different parts of the world, it is doubtful if any or all of them have done more to bless mankind than the Bessemer converter.

Metallurgy also holds intimate relations to the art of agriculture, since, in the manufacture of steel from ores and pigs rich in phosphorus, a most valuable fertilizing material, a basic phosphatic slag, has been developed, over a million tons of which are used annually to increase the food supplies of the world. This fact is an illustration of the very intimate relation which chemical research establishes between all the arts and sciences into which it enters.

The science of chemistry has undergone such a wonderful evolution during the past one hundred years as to make some of its branches almost strangers to others. The term chemist at the present day no longer indicates one who is thoroughly acquainted with the entire science of chemistry, but rather one who practices some special branch of the science. There is no living man who can be said at the present time to understand the science of chemistry as a whole, in the sense of expert knowledge. It is true that one who reads the literature of the day, even in the form of extracts, may have a general knowledge of advanced chemical science and the broad principles upon which it rests. But it requires a lifetime devoted to a special study to become an expert in that line. As illustrated by the intimate relation between two branches of science, apparently so remote from each other as the two cited above, it is evident that there is no real separation between any two lines of chemical research, but that all the workers in this science should recognize their universal fraternity.

Another very apt illustration which will occur to every one, of the influence of chemical research on industrial art, is seen in the development of the coal tar coloring dyes. Fifty years ago coloring matters were mostly natural products, and very few artificial coloring matters were known save those produced by grinding metallic oxides in oil. The vegetable world was the source of a great many of the principal dyes employed in the textile industries. Indigo, madder, turmeric and other vegetable coloring matters were the principal ones employed in the dyeing of many fabrics. To-day we find a complete change in the technique of coloring. From an apparently waste product there have been developed a series of colors which are at once brilliant, permanent and cheap. The development of this industry was due solely to chemical research, without any idea of practical application. As soon, however, as it was discovered that coal tar contained the basis of so many varying tints, rapid strides in their practical application to the textile arts were made. To-day, if the coal tar colors were removed from this industry, it is no exaggeration to say that paralysis would ensue and the capital invested in it, of hundreds of millions of dollars, would be compromised.

Not only in the textile fabrics has this great influence of chemical science been felt, but even in the case of the colors used in food products we find that the coal tar tints are gradually replacing the natural vegetable coloring matters in the markets. We find that candies, confections, preserves, jams, jellies, butter and oleomargarine, at the present time, are colored by tints made from synthetic products, to the practical exclusion of the natural vegetable coloring matters, which, a few years ago, were used altogether. I say nothing here in regard to the hygienic effect of this change; that is a matter which could only be properly discussed upon another occasion. I have spoken only of its commercial aspect, and have endeavored to present to you the triumphs achieved by chemical science in rendering the products of nature more expensive than those of synthetic chemical skill.

This fact leads to the discussion of another very important rôle of chemical discovery in the industrial arts, namely, the continued manufacture of synthetic products, which are cheaper and, therefore, commend themselves more generally to the public use than those formed by the ordinary processes of nature. Chief among these may be mentioned the hundreds of materials now used in pharmaceutical preparations. I have very little to say in favor of the use of drugs and medicines of any description, but in this general review of the accomplishments of chemical research one cannot shut his eyes to the fact that in pharmacy the synthetic relations of chemistry have assumed a very important position. One has only to look over the list of remedies, both official and proprietary, to see the great inroads the chemical laboratory has made upon the fields which heretofore were supposed to be reserved only for natural products. The old natural remedies of herbs and roots are now very largely superseded by the artificial products of the retort and the crucible.

In the case of beverages, we find that a change has been wrought, also, in the substitution, for products made by natural methods, of those produced by chemical synthesis. Especially is this true of those beverages which depend largely for their reputation .and flavor upon the ripening influences of age. It is well known that certain kinds of beverages, such as wines and the distilled liquors, known as whiskies and brandies, when properly supervised and kept, become mellower, more palatable and more wholesome with the passing of time. These changes, which are so appreciated by the consumer, are due solely to chemical reactions which the liquors undergo. In the crude state they contain alcohols which are both unpalatable and unwholesome. Slowly, under the proper conditions, these alcohols are oxidized to form the ethers and other aromatic compounds, which add to the odor and the flavor of the beverage and make it more palatable and more wholesome. The chemist was not slow to discover the nature of these changes, and to produce in a synthetic way, in his laboratory, the exact substances which nature produces in the ripening process. It was found that all these ethers and aromatic substances could be made in the laboratory, and at a much less expense than they could be produced in the bonded warehouse, by natural methods. It was, therefore, possible to mix a pure alcohol with the necessary ethers, essences, flavoring and coloring matters, in the composition of an exact counterpart of a very old whiskey, and this mixture could be made so skilfully that both the chemist and the connoisseur would be puzzled to discover any difference between the genuine and artificial beverages.

Perhaps I should say a word here, also, in regard to the claims which have been made in many quarters that chemical science will eventually permit the synthetic production of human foods, to the practical exclusion of the ordinary pursuits of agriculture. These predictions are not without some foundations in fact, for since the day, now three-quarters of a century ago, when Wöhler and Chevreul succeeded in passing the border line which had been supposed to separate the inorganic from the organic world, and produced actual organic compounds, hundreds of substances of an organic nature have been formed directly by chemical synthesis. Among those bodies which could serve as foods, the fats and sugars are the most prominent, while it is only of late years that bodies having the properties of protein matter have been formed by synthetic operations. Since animal bodies are sustained almost exclusively by food of an organic nature, it is evident that all progress in this line has some bearing upon the food of the future. The fact remains, however, that all these organic compounds are produced at such an expense as to render them practically impossible for food, even if they possessed all the digestive properties necessary to nutrition. Further, it may be said that organic synthetic products do not seem to have the same relation to the digestive enzymes as is held by the natural products. It seems, therefore, unwise to expect even in the remote future that any considerable part of the food of man will be produced directly by artificial synthesis.

It is true that several distinguished men of science have prophesied the coming of the day when such a consummation would be fulfilled. Chief among these may be mentioned Berthellot, the distinguished French savant, who has foretold the day when all the cultivatable area of the world will be nothing but one grand pleasure park and the surface of this beautiful earth will no longer be desecrated by the vulgar plow. Man, removed from the necessity of toil and living upon the bounty of the chemist, will devote his time to study and pleasure, and the millennium, so long expected from theological sources, will at last have come about from the accomplishments of the chemist.

These ideas must be characterized as dreams of the vivid imagination or as the pleasantries invoked for the amusement of an audience, rather than as the sober deductions of scientific truth. I have already indicated the magnificent work which the chemist is doing and is to do for agriculture, but it is not along the line just indicated. The remotest future that the scope of our imaginations can picture, in my mind, will see the food of man produced in the fields and the science of agriculture developed to the highest point of production, chiefly through the accomplishments of chemical science. But, in denying to chemistry the possibility of a complete triumph in the production of all human foods, I do not mean to imply that the prosecution of chemical synthetic research and its application to the industrial arts will not do much to ameliorate the condition of man.

A mere glance at all our industries of the present day shows how great this amelioration has already become. The capacity of the laboring man to produce useful things, both in the field and in the factory, is increasing day by day, and this increase is due, in my mind, chiefly to the accomplishments of chemical science. It is true that labor-saving machinery has done much, but labor-saving machinery of itself would tend to diminish the demand for labor, and thus to increase the burdens of the laborer. Were it not for the fact that labor-saving machinery, which spares the hands and muscles of the laborer from much drudgery, is accompanied with scientific research, which places the powers of nature more certainly within the control of man, it might prove a curse instead of a blessing. In point of fact, the improvements in labor-saving machinery have been accompanied with an advancement in our knowledge of the laws of nature and of the methods of utilizing to the best advantage the raw materials at our disposal. The sum of all these accomplishments is that a day's labor to-day produces many times more than the result of a day's labor 100 years ago. And this has been accomplished, happily, not by diminishing the compensation paid to the laborer, nor by increasing his hours of work, but, on the contrary, by decreasing his hours of work and increasing his compensation.

A few days ago I was in conversation with an octogenarian who, having amassed a competence, has retired from active business. He said: "Fifty years ago, when I was in active life, money was worth 10 per cent. per annum, and labor could be had at 50 cents per day. Now," he said, "money is worth only 4 per cent. per annum, and labor is worth $1.50 a day." This is a fact which students of sociology should not lose sight of. Unfortunately, most of the so-called sociologists of the present day are pessimists of the worst type. By their ill-based lucubrations they disturb rather than pacify the public mind, since they convince the laboring man that his condition has never been so bad as it is at present, while in point of fact it has never been so good. All the forces which, in the eyes of some people, tend to depress labor, on the contrary, work to elevate it. It is true that among our skilled artisans the day of the journeyman and apprentice has practically passed away. Scarcely any one at the present day learns to do everything in any trade. Each portion of the work is specialized, and the artisan becomes as much of a specialist as the scientist. Even the "man with the hoe" can earn his $1.50 a day, and while he may not be a master of French art, he finds in his life plenty of opportunities for improvement and culture. His children go to the best schools; his daughter has an organ in her parlor; the family sits at a table spread with wholesome food in abundance; the morning paper brings him the news of the world, and in the grocery store of the village he finds the fruits and delicacies of tropical lands, mingled with the products of the fields about him. The "man with the hoe" of to-day enjoys more opportunities for culture, more of the joys and luxuries of life than did the millionaire of Athens and Rome 2,000 years ago.

We must recognize this state of affairs as progress, any comprehensive study of which will not fail to reveal the master hand of science in it all; nor will it be difficult to see which science has been the most pregnant factor in producing this fruition at the beginning of the twentieth century.

We find in the achievements of science, and in their applications to practical life, the solution of the great problems which have been the theme of philosophers and poets from the beginning of time. The aspirations of the latter and the logic of the former have from the earliest history of mankind been directed to the amelioration of man's condition.

Whatever be our opinion of the theological view of the origin of man, there is one thing in which we must all agree, theologian and scientist alike, and that is the necessity of labor. What the theologian calls the curse of labor, the scientist regards as the glory of mankind. Labor is only a curse when it monopolizes the whole energy of the individual, but it is a blessing when it directs the forces of man into useful channels of expression. The great work of science, therefore, for man, is to change the curse of labor into the blessing of labor, and this it is rapidly accomplishing.

I am not one of those who look at the achievements of science in the distant future to see the passing away of the necessity of labor. If the conditions foretold by Berthellot could be accomplished, and man were left at ease in the beautiful garden of his own creation, all the incentives which produced his power would be taken away and retrogression would take the place of progress. It would not be difficult to foresee the time when this very park of pleasure, built by man, would become again a wilderness, in which man and the lower animals would contend for supremacy. Science, by directing man's labor into profitable channels, will make it a means of his own advancement, and the exercise of his faculties will prepare him to enjoy the fruits of his work.

No matter how tempting a feast, both in the quality of its constituents and in the manner in which they are served, it has no attractions for the man without an appetite. Hunger is the prime factor in the enjoyment of a banquet. In like manner one cannot enjoy rest and the pleasures which it brings who has not worked hard enough to make himself tired. Fatigue is the prime factor in the enjoyment of leisure. So even if science could do what some few enthusiasts claim that it can, it would remove from man the necessity of labor, which, when rationally employed under the direction of science, is the source of his greatest comfort and pleasure.

In what has gone before, a few of the most important ways in which chemistry has come into contact with the progress of the industrial arts have been set forth. In the destructive arts and industries, also, the intimate relations of chemistry are quite as well marked. I refer, of course, to the art of war. The radical changes in the art of war have been due chiefly to chemical research. These researches have been devoted mostly to the elaboration of more powerful explosives. In ancient times, before the invention of gunpowder, battles were fought by the actual coming together of the participants. There was added thus to the horrors of war the bitterness of personal contact. Modern warfare is almost wholly removed from the possibilities of battle by personal contact of soldiers with the enemy. Thanks to chemical science, those who engage in battle are constantly widening the line between the two opposing armies, so that the modern battle is rather a test of chemical skill than a trial of physical prowess. Little by little chemical research has invented means for carrying projectiles further and with greater destructive force. These advances have been met by a recession of opposing forces, so that in point of fact the destruction by battle is decreasing rather than increasing with the invention of better explosives and improved firearms. One hundred years ago a naval battle was not thought to be complete unless the two opposing ships came into actual contact, and the victors boarded the vessel of the vanquished. The slaughter in such cases was something frightful. In our last naval war, armored vessels, securely riding the sea at a distance of one or two miles from the enemy's fleet, proceeded to the bombardment more as if performing an evolution than as if engaging in actual battle. As a result of the application of chemical science combined with mechanical skill, the victors in the two great recent naval battles scarcely lost a man, and the sailors of the defeated vessels were quickly picked up and preserved by their conquerors. The dictates of humanity require that if a war is to be fought, it should be short, sharp and decisive. Chemical invention has rendered it possible to bring even a great war to a speedy close, with an aggregate saving of human life, so that even in the destructive arts and industries chemical science has done much, not only in the accomplishment of speedy results, but also in the conservation of human life.

When it comes to the care of the wounded, chemical science again claims a share of the glory. The antiseptic treatment of wounds is due solely to the study of the causes which formerly made wounds so fatal. At the present day, if the skilled surgeon can reach the wounded man in time unless the actual loss of tissue is so great as to bring about a fatal result, the sufferer can be saved. The inflammation and the gangrene which have caused the deaths of so many soldiers after the battles of the past are now practically unknown in the light of modern chemical surgery. Chemistry has furnished not only the theory on which the antiseptic treatment of wounds is based, but the materials which make it possible.

Finally, it may be said that chemical science stands in a fundamental relation to all the principal arts and industries of the world. It also, by making possible an amelioration of the condition of mankind, has done more probably than any other science for what is known as the "humanities."

In former times a liberal education practically excluded the sciences, chiefly because they were not well known, and because they were not considered necessary to the liberal arts. All this is now changed. While we still value and cultivate the old classical and mathematical learning, we have added to it the training in the sciences, which makes the student at the time of his graduation better fitted for the battle of life. For life at best is but a battle, and war, after all, is the normal condition of mankind. It was the struggle for existence that first brought man from the level of the lower animals to have dominion over them. It was the battle of one tribe with another that enabled the superior race of men to people the earth. It is struggle with his environment that develops the power and the precedence of the successful man. While deploring the horrors of war, the sober student of science must admit that it has its uses. Not only does war and struggle bring power and dominion, but it brings also responsibilities and duties which science will show man how to meet and discharge.

The time has passed when the scientific man is regarded as a recluse. He must take his place in the foremost ranks of progress; he must teach his race their powers and their possibilities; he must show struggling humanity the way to succeed and the way to happiness; he must come into contact with the State; he must show the loftiest patriotism and the greatest willingness to assume and practice his privileges as a citizen. In all these duties the chemist will have his full share and chemical science its proper place.

If we may look for one moment at the future, I think we may safely say that in the days to come the progress of chemistry will enter into more intimate relations with the useful arts and industries, and chemical science become a still greater blessing to mankind.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.

THE MAKING OF PHOTOGRAPHY.

BY CHARLES F. HIMES, PH.D., LL.D.

CHARLES F. HIMES.

Standing at the close of three-quarters of a century, marked by intense scientific activity attended by amazing progress along all lines, the most superficial consideration of photography and its applications exhibits it as one of the most important factors in the life of to-day, evolved from that activity. Using the term in its most comprehensive conventional sense, it touches at numberless points all sciences, all professions, all trades and industries. It would be a hopeless task to compress into the limited time, very properly assigned to this the most recent branch of this Section, on this occasion the most imperfect statement of the achievements of photography, to say nothing of indulgence in speculations as to its further possibilities. But the occasion does not seem to require it. It belongs to the Franklin Institute, and at this, its seventy-fifth anniversary, it seems appropriate to consider photography and its history in its relations to the Institute, for photography and the Franklin Institute were young together. They have grown up together. It has had a share in the making of modern photography. When the Franklin Institute was founded, the word photography had not been coined, or at least had not struck the ear of the lexicographer. It may have been one of many words used according to the fancy of the individual investigator to connect the accumulating facts of an inchoate branch of science; but it was not the first, and when it did put in an appearance, it was not free from adverse criticism. There was a time when heliography may have been preferable, but with the extended industrial use of the electric light, magnesium light and even gas light, to say nothing of the Röntgen rays, it would be much more of a misnomer to-day than photography, which word must be regarded as holding its place to-day, as the survival of the fittest. It is an interesting coincidence, too, that the year that witnessed the founding of the Franklin Institute is, perhaps, the most important in the history of photography. It was not, it is true, the year in which any important discovery was made or announced. It was simply the initial year of those experiments that culminated in the discovery that constitutes the birth of modern photography. It was in that year that Daguerre first turned his attention to photographic investigations. For after all has been allowed that is to be credited to, or even claimed for others, he still remains the central figure in photographic history. Photographic events date backward and forward from him. Without his discovery all photography that preceded him would have been embalmed in the history of science, overlooked and perhaps entirely lost, until revived by the touch of some such great discovery as his. His success at once caused all records to be ransacked, to be assured that he had, indeed, made so unique and marvellous a discovery. As usual in such cases, some things were found that at first sight seemed to reduce his claims, but which, when fully considered, do not affect them in the least. In 1824, then, he entered upon the fourteen years of solitary, discouraging, almost hopeless, but unintermitted experiments, that finally resulted in the discovery to which his name has adhered. Accustomed as we have become to the almost daily announcement of similar great unexpected and unheralded discoveries, we can hardly realize the sensation it created, nor the struggle between the great desire to believe it true, and the incredulity of that day, so much greater than that of our own. This was even heightened about that time by the then recent "Moon hoax," to which the announcement of Daguerre's discovery was compared, even by scientific men. In his classical history of chemistry, Kopp, who doubtless wrote from personal acquaintance with individuals present in Paris at the time, in seeking for a parallel to the excitement occasioned by Davy's great discovery of the metals of the alkalies, in the early part of the century, says of it, "something like that occasioned by Daguerre's discovery in our time." From that date, 1839, we pass rapidly backward into the hazy prehistoric period, that belongs to every branch of science, from which many interesting items have been recovered by the curiosity aroused by the practical success of his process. From that date forward, we have only to note an immediate, rapid, steady development. There is no disposition by this statement to unduly magnify the merits of Daguerre, much less to minify the claims of others, but simply to accentuate the epoch-making character of his discovery. So much has been written with a bias, in many cases inspired by national partiality, and is being so frequently repeated, that the salient and indisputable facts are often overlooked. It may not, therefore, be out of place here to bring together rapidly facts generally received, in such connection and sequence as to exhibit the origin and making of modern photography.

What then was the condition of photographic research in 1824? Overlooking all alchemistic and other accounts, however curious and interesting, but without effect upon the history of photography, we find, in 1777, the illustrious Swedish chemist, Scheele, engaged in investigating scientifically, carefully, we might almost say exhaustively, the interesting fact, long known, that silver chloride darkens under the influence of light. He allowed sunlight that had passed through a prism to fall upon silver chloride spread upon paper on the floor of the darkened room, and demonstrated that the violet ray was most effective in producing the change. He further established the fact that chlorine was liberated in the operation. But this, the usual, statement of these facts, and a correct one from the point of view of to-day, conveys a very wrong impression of Scheele's purpose, and of his interpretation of his results. The object of his investigation was not the action of light on silver chloride, but the action of silver chloride, or horn silver, as it was then called, on light; and he did not state his results in the way given. The scientific world of that day was dominated by the curious, almost fanciful, phlogiston theory of combustion. That hypothetical something, or nothing, was always present in their thoughts whilst investigating. Scheele was trying to demonstrate that phlogiston was present in sunlight, and he explained his results by saying that silver calx removed the phlogiston most rapidly from the violet ray. The change in the silver chloride he explained as loss of dephlogisticated spirit of salt. Disentangled then from the theories of his day, Scheele made two important discoveries, which we recognize to-day as photographic. Many eminent investigators repeated his experiments. In 1798 Rumford, as the result of elaborate experiments, contended that the change was due to heat, and not to light. In 1801 Ritter, incited doubtless by the detection of heating effect, by Sir W. Herschel, the year before, in the space beyond the red of the spectrum, announced the discovery of photographic effect in the invisible region beyond the violet. He also demonstrated an opposition of effect of the red and violet rays, and explained it by an oxidizing action of the former, and a reducing action of the latter. In 1802 Wollaston arrived at substantially the same results; but in investigating Ritter's explanation of the opposition of the red and violet rays, from which he dissented, he employed a photographic substance of a new class, namely, gum guaiacum, and considered its change of color under the influence of light. In 1804 Young employed a silver salt successfully to investigate Newton's rings, projected by a solar microscope. So Vogel, Seebeck, Senebier, Davy, Berard, in fact almost every scientific man of prominence of that period, pursued similar lines of investigation. The motive of most of these was strictly scientific, such as the determination whether the solar beam contained three essentially different agents, of which the actinic was but one, the photogenic production of the colors of the spectrum, the exploration of the invisible regions of the spectrum, and the like. In the apparent chaos of carefully observed facts, there are many that advanced photography of to-day imparts new interest to, and that might well repay reinvestigation. There was but one notable attempt at practical application of facts. In 1802 Thomas Wedgewood, son of the porcelain manufacturer, in connection with Davy, published a method of copying pictures painted on glass, fibers of leaves, wings of insects, and so forth, by pressing them in contact with paper coated with nitrate or chloride of silver and exposing to sunlight; but, failing in all their efforts to prevent the continued darkening of the pictures obtained in this way by the action of light, they were obliged to preserve them in the dark, and could only examine them by candlelight.

During the decade preceding the founding of the Institute there was almost a complete lull in scientific activity along these lines. During this time, however, there was one man, Nicéphore Niépce, who had been working on from 1814, with great tenacity of purpose, trying to fix the images of the camera. He had sufficient suggestions of success to keep him at work. He did not approach the subject from the scientific side, nor from purely scientific impulses, but with a desire for immediate practical results. He had become interested in the recently-discovered process of lithography. The difficulty of procuring suitable stone suggested the use of metallic plates, and it occurred to him to substitute light for the hand in drawing the pictures. After experimenting with various substances, among them silver chloride, he discovered that bitumen of Judea was rendered insoluble in certain solvents by the action of light. He coated metallic plates with a thin varnish of it; exposed them when dry to the sunlight under engravings, previously varnished to render them more transparent, and then dissolved out the unchanged bitumen of the parts protected from the light. After a measure of success in thus copying engravings, he experimented with the pictures of the camera on similar plates, and there seems to be no question that about 1827 he had obtained pictures by this process, however imperfect. He named the process "Heliography."

In 1824, Daguerre, entirely ignorant of Niépce or his work, entered upon a similar pursuit, upon parallel lines, inspired by a similar desire for immediate practical results. He was a scene painter in Paris, and an artist of no mean character, and of great popularity in that city. The diorama, invented by him, was the sensation of the day. Crowds were entertained by its surprising effects. He was aided by the camera in preparing his scenes. The wish to fix its fleeting pictures might occur to any one, but it took complete possession of him, although the pursuit was more unpromising than that of the alchemists. He worked alone and in secrecy, with but little encouragement. His methods were empirical rather than scientific. About 1826 he learned of another worker in the same field. He immediately wrote to him. Niépce, distrustful of the unknown writer, threw the letter in the fire. A letter a year later met with a better reception. The correspondence continued, at first with almost suspicious reserve. Niépce visited Paris, met Daguerre, was greatly impressed with his diorama. Both seemed to enjoy an exchange of experiences that belonged to them alone. Niépce wrote his son, that Daguerre persisted in regarding his (Niépce's) process as better than his own, but that one thing was certain, they were entirely different. A partnership, styled Niépce-Daguerre, was formed, with equal interest. The article of agreement, dated December 14, 1829, was signed by Niépce as "Land owner at Chalons sur-Saône," and by Daguerre as "Artist-Painter, Member of the Legion of Honor, Manager of the Diorama." Under the terms of the partnership, Niépce contributed his process of Heliographie, and his experiments, which Daguerre agreed to assist in improving, and also contributed his improved camera, which was regarded as of great value, as it most likely was. Daguerre improved the process, but was diverted altogether from it by the accidental discovery of the sensitiveness of silver iodide to light. In the bitumen pictures the blacks of the original were represented by bright polished metal, from which the unchanged bitumen had been removed, and the whites by the changed bitumen. To convert these negative pictures into positives, Niépce experimented with a variety of substances, among them vapor of iodine, to darken the exposed metal, and then dissolved off the bitumen from the whole plate. It is said that Daguerre observed, that the shadow of a spoon that happened to be lying on a polished silver plate that had been exposed to the vapor of iodine, was permanently impressed upon it. Slight as every one knows this direct effect of light on iodide of silver to be, Daguerre seemed to see in it new possibilities for camera pictures. Niépce, however, after experimenting with it at Daguerre's suggestion, expressed regret that he had lost so much time in following his recommendation. He repeated that he did not see that they could hope to secure any advantage from this process, and suggested other substances as better. Niépce died in 1833. Success seemed as remote as at the formation of the partnership. The partnership was renewed with the son, Isidore Niépce. Daguerre now entered with even greater enthusiasm and undivided effort into the pursuit. He neglected the diorama, and lived in his laboratory, to which no one had access, not even Isidore Niépce. He became so much wrought up by his unsuccessful experiments that his wife, according to Dumas, consulted physicians in regard to his sanity. Finally there came to his assistance an accident which conducted to a fundamental discovery, as fundamental to-day as it was then. The mode of the discovery has not only a species of romantic interest of its own, but, as I recollect it, given by Professor Liebig in one of his lectures, as one of the finest specimens of the inductive method, coming thus from one thoroughly familiar with the Paris of that day, it has an added air of authenticity that may excuse the narration of it in this connection. Daguerre's method of experimenting was to expose polished silver plates to the vapor of iodine until coated with a layer of iodide, then to subject them to the image in the camera. These plates, always without the hoped-for result, or at most the very feeble direct effect, were repolished, reiodized, re-exposed in the camera with the same disheartening results. On one occasion, upon removal of such an exposed plate from a closet, in which it had been stowed, to repolish it for a new experiment, to his great surprise he found upon it the view to which it had been exposed in the camera, not an uncertain, feeble picture, such as he had been accustomed to, but a strong, clear, unmistakable one. He exposed another plate in the camera, without visible effect, stowed it in the closet, again to find the invisible picture put in an appearance. He had no way of explaining the result. All his years of investigation furnished him no clue to the influence at work. He set about systematically to discover it. He could only conclude that it must be something in the closet. He placed plate after plate, after exposure in the camera, in the closet, each time first removing something from the closet. Each time the invisible became visible. At last nothing remained but some mercury spilled on the floor of the closet. Thus by this method of elimination the magician was detected. It was a short step to subject plates that had been exposed in the camera to vapor of mercury, and the daguerreotype process was complete. But the discovery was far more than simply that of a process. It was that light can produce an invisible effect, a latent effect, as it has been called, previously entirely unsuspected, which may be rendered visible by suitable agents, which we call developers, and, what was of most practical value, an effect produced in so short a time as to render camera pictures easily possible. Upon it all modern photography, the prime factor in which is the negative, is based, and a great part of the photographic literature of to-day deals with development and developers. If one name, then, is to be selected as representative in the history of photography, there can be no question but that it should be that of Daguerre. This seems to have been the view taken by the authorities of the Congressional Library at Washington, and there was a singular fitness in placing his name there with that of Guttenberg in the Hall of Inventors. The name of Niépce might have been placed there too, but certainly in a subordinate position, or have been left out, as it has been, without manifest injustice, although his merit is of a high order. He was an independent, ingenious, indefatigable experimenter and investigator. His bitumen process may be regarded as entirely his own, although the important principle underlying it, of change of solubility effected by light, to-day of widely-extended application, was, at least, suggested to him, according to a letter by him, by the experiments of Wollaston with gum guaiacum, which experiments, however, his own failed to substantiate. Although his process was measurably successful, it was extremely slow as a camera process, requiring from six to eight hours in the sunlight, and not only imperfect, but impracticable, and, looked at even from our present point of view, had in it no possibility of growth or development into a practicable camera process. There is nothing in it in common with, or suggesting in any degree, the negative processes of to-day, and, however creditable his work and its results, photography, as we understand it, would have begun and ended with Niépce and his process. The discovery of Daguerre, however, of a latent effect of light, produced in a much shorter time than any direct effect and developable, was a unique fact in science. It was independent of, and unsuggested by, anything that had preceded it. The guesses of Sir John Herschel in regard to it, after its announcement and before its publication, accentuate this important fact. It was in the line of his investigations, and in commenting on Daguerre's concealed process, as he termed it, he gave four possible explanations of it, no one of which proved to have anything in the remotest degree in common with it, as published a few months later. It had in it all the possibilities of the negative processes of to-day, in which time of exposure has been reduced to the smallest fraction of a second, as shown in the kinetoscope and the snap shots of the amateur. The development of modern photography, with all its practical applications, from it was like the growth, and very rapid growth, from a germ.

Had this fact been left by Daguerre with simply the suggestion of a practical application, its importance would have been the same. But he gave a process founded upon it commercially complete, immediately available, with results possessed of highest intrinsic merit, which contributed much to the growth of practical photography. An account from a Parisian newspaper of the day will serve to emphasize this statement as to the character of the results: "The deputies" (of the French Assembly) "during the day crowded to the room attached to the Chamber of Deputies, in which the pictures were displayed." "They were struck with the marvellous minuteness of detail which these views, especially those of the streets, exhibited." "In the one of the Pont Marie all the minutest indentations and divisions of the ground, or the buildings, the goods lying on the wharf, even the small stones under the water at the edge of the stream, and the different degrees of transparency given to the water, were all shown with the most incredible accuracy. The use of a magnifying glass revealed an infinity of other details quite undistinguishable by the naked eye, etc." This might be taken as the description of a first-class photograph of to-day. But it may be said, after all, it was only the result of a happy accident. That could be said of many discoveries. The list of such accidents to purely scientific men would be a long one. But such accidents only happen to such men as work their way across their paths, and can appreciate them, otherwise they come and go unnoticed. The accident is frequently the final event of a long series that seems to be credited with too large a share of the ultimate success. Daguerre was a lucky fellow, but he was not a scientific Micawber. The commercial reception of the discovery is interesting, perhaps instructive. In 1838 the process was considered so far advanced as to be put in operation. From March 15th to April 15th subscription books were kept open for 400 shares of 1,000 francs each. Not a share was taken. The process was offered for 200,000 francs and no purchaser appeared. In January, 1839, the secret was imparted to Arago, who was so impressed by it that he exerted himself to procure recognition for it from the French Government, which pensioned Daguerre and Niépce, and gave the discovery as a gift to the world, without the restriction of a patent, except in England, where one had already been taken out. On the 10th of August, 1839, the process was communicated by Arago to a joint meeting of the Academy of Sciences and the Academy of the Fine Arts, held for the purpose. The Mazarin Palace in which the meeting was held was not only filled with an audience of unusual character, but the approaches to it were crowded.

This early period of photography cannot be passed over without mention of the name of Henry Fox Talbot, of England. He was a man of many-sided scientific character, and an independent investigator in the photographic field prior to Daguerre's discovery, and therefore not inspired by it to investigation. In 1839, January 31st, he read a paper before the Royal Society, entitled "Some Account of the Art of Photogenic Drawing, etc.," embodying a practical process on paper based on the abandoned process of Wedgewood and Davy, which he improved and also completed by fixing the pictures, although imperfectly, in a solution of common salt or potassium iodide. The substitution of sodium hyposulphite, first suggested by Sir John Herschel, for the iodide soon followed. He further suggested indefinite photographic multiplication of the paper originals, by taking impressions from them on similarly prepared paper, and upon the publication of Daguerre's discovery of a latent effect of light, was quick to apply it to the preparation of a paper sensitive enough for camera impressions; and by rendering these transparent, greatly facilitated indefinite photographic multiplication of the original negatives as positive pictures, although the terms negative and positive, in this connection, were first used by Herschel. His Calotype process was patented by him in 1841. Although there is nothing in it that would call for the association of his name with those of Daguerre and Niépce, yet, as an independent investigator, scientifically trained, he deserves prominent mention, as one whose applications of known facts at once greatly stimulated the practice of photography and its consequent rapid improvement. In addition to the introduction of photographic multiplication by the use of a translucent support for the sensitive compound of silver, the replacement by him of the formation of such a compound by the direct combination of the halogen with the silver, as in Daguerre's process, by the reaction between silver nitrate and a metallic haloid, was typical of more modern photography.

It is interesting at this point to note the reception of the discovery in America. There was at least one man thoroughly ready to appreciate the scientific features of the process and to apply it. The numerous papers contributed to the *Journal of the Franklin Institute* by Dr. John W. Draper, several years before Daguerre's discovery, detailing investigations, are classical, and surprise us even to-day by their minute accuracy and anticipation of solutions of questions long subsequent. But he escaped making Daguerre's discovery. He succeeded, however, in doing what Daguerre had not yet succeeded in accomplishing. He took the first portrait by Daguerre's process, although, as we shall note, this claim is disputed in favor of a Philadelphian. He took the first photograph of the moon. He applied the process in a variety of ways in scientific investigation. But nowhere did the announcement lead to practical application as quickly as in Philadelphia. The old American Philosophical Society and the then young Franklin Institute had members alert for anything that was new in science. Joseph Sexton took the first photographic view in America, out of a window of the Mint, with very crude apparatus in October, 1839. Robert Cornelius, a lamp-maker, took a portrait in the latter part of 1839, some claim before that made by Draper. The Franklin Institute, in its exhibition in 1840, displayed some of the first results. The *Ledger*, in its account October 12th, states: "Throughout the room are various specimens of the daguerreotype. They consist mostly of miniatures." This shows great enterprise for a day of sailing vessels, when it is remembered that Daguerre's process had only been made public in Paris in August, 1839. But the part that Philadelphia had has been so fully treated in a lecture before the Franklin Institute several years ago by Mr. Julius F. Sachse* and published in its *Journal*, that I can do no better than to refer to it. But one fact of permanent effect, and of exceeding interest in this connection, is the strong body of amateurs in the art which sprang up in Philadelphia, and which has always characterized it; strong not only in numbers, but in scientific character and motive.

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* Sachse, Philadelphia's Share in the Development of Photography, *Jour. Frank. Inst.*, **135**, 271.

I think I am not mistaken when I assert that the first independent photographic society in America was the Philadelphia Photographic Society, as the American Philosophical Society was the earliest scientific society. It was organized in the heroic days of photography, when the practice of photography meant a great deal; when press-the-button and snap-shot work were unknown. Members of the Philosophical Society and of the Institute were active in founding it and making its creditable records. Dr. Coleman Sellers, President of the Institute, was a prolific writer on photographic subjects, always instructive and practical. Joseph M. Wilson, who is doing so much to give Philadelphia pure water, also a former president, has been an enthusiastic amateur from his boyhood. There are so many others, who have not filled that high position, active in advancing photography, that I must refrain from mentioning any, except Mathew Carey Lea, so well known as one of the most indefatigable, painstaking scientific investigators, whose contributions to this subject, largely along lines all his own, are not only of present practical value, but full of promise to investigators, which the future will doubtless realize. His apparatus bequeathed to the Franklin Institute will form a fine nucleus for the encouragement of photographic investigation. When Professor Henry Morton, then Secretary of the Institute, organized the highly successful expedition to photograph the total eclipse of 1869, under the auspices of the National Government, he was able to draw largely from the membership of the Institute for his efficient corps of observers.

But to return to the development of photography. One of the most tantalizing defects of the process, as published by Daguerre, was its slowness. It suggested portraiture, but just came short of desired success. In 1840 the requisite increase of sensitiveness was obtained by the use of bromine in connection with iodine, and the trio of silver haloids in use to-day was completed. This use of bromine as an accelerator, as it was called, was published by Goddard, of London, in 1840. The honor of its introduction is also claimed for Philadelphia, where Dr. Paul Beck Goddard, a singular coincidence of names, employed it as early as 1839, but, as he kept the fact a secret until 1842, whilst we are privileged to believe that he first used it, we cannot claim the honor for him as against prior publication. The process, it seems, was employed at once commercially here with greater success than in France. Daguerreotype portraits were taken at five dollars each. The Calotype negatives of Talbot, with the objectionable grain of the paper, suggested better things. Glass had been used by Herschel in some experiments with silver chloride, and negatives on glass, with albumen as the vehicle of the silver iodide, which afforded excellent paper prints, were first produced by Niépce de St. Victor, nephew of Niépce, in 1847. The daguerreotype began to recede in importance, and amateur practice of photography was stimulated. In 1850 the greatest advance since the time of Daguerre was made by the introduction of collodion, a solution of guncotton, then recently discovered, as a vehicle of the sensitive silver iodide. Glass and collodion seemed to possess all desired properties for photographic purposes. Nothing better seemed possible. The daguerreotype disappeared entirely. A collodion positive process on blackened metal, an American invention, in a measure took its place, and survives to this day as the tintype. The collodion process, however, was soon found uncomfortably cumbersome by the growing number of amateurs, requiring as it did the completion of the whole process whilst the plate was still wet, necessitating the impedimenta of tents, bulky solutions, fragile vessels, etc., for outdoor work. The dispute continued for a decade between *humidus* and *siccus* as to the relative merits of the wet process and various dry-plate processes devised from time to time. At last, in 1862, the tannin dry-plate process of Major Russel seemed to be satisfactory in results, but slow in exposure and time-consuming in the preparation of the plates. In the wet-collodion process the metallic haloid was added to the collodion and the plate coated with it immersed in a solution of silver nitrate, where the reaction took place producing the silver haloid. The question naturally arose, why not eliminate one of the most troublesome factors of the process by adding the silver salt to the collodion? In 1865 Bolton & Sayce overcame the intrinsic difficulties, and produced an emulsion of silver haloids with collodion suitable for the purpose. The process became commercially available, and bid fair to revolutionize photographic practice. But in 1871 Dr. R. L. Maddox succeeded in producing workable plates with an emulsion of gelatine and silver bromide. The process was at once taken up, and brought by rapid stages by different workers to a high degree of perfection. Dry plates of wonderful rapidity, of great certainty and ease of manipulation and of practically indefinite keeping qualities were soon placed upon the market. Again a Philadelphian, and member of the Institute, John Carbutt, manufacturer, was among the very first to recognize the commercial possibilities of the new process and erect a plant to meet the demand sure to spring up. The professional adopted them slowly. The amateur recognized in them the long-desired dry plate. Photographic societies in the United States, mainly of amateurs, increased in the decade from 1883 to 1893 from 9 to 120, or more than twelvefold. Manufacture of cheap, but good, dry-plate outfits, which dispensed with the more expensive wet-plate holder, assumed very important proportions. Dry plates and improved developers and appliances for dry plates began to predominate in the advertising columns of the journals, and detective cameras, as hand-cameras were generally called at first, were largely advertised in periodicals in which photographic advertisements had not appeared before. But the amateur complained now of the weight of glass to be carried. A return to paper for negative purposes was made, expensive apparatus devised to coat it and with excellent results. The critical amateur withheld his patronage. At last a substratum was produced in celluloid, singular to say with guncotton as a chief ingredient, having the essential photographic properties of glass, but tough as well as light. But still the enthusiastic, patient amateur, with almost infinite capacity for trouble, but always seeking lines of least resistance, striving to avoid the unnecessary in his work, and keenly sensitive to discomfort, complained that he had to retire to the dark-room or changing bag before his day's work was half done. Again his complaint was met by the daylight loading roll of sensitive film, which will permit a year's snap-shotting without entering the dark room.

The discovery by Professor Vogel, in 1874, of the possibility of rendering plates sensitive to colors generally regarded as non-actinic, by treating them with suitable dyes, constituted the most distinct advance in photography since the days of Daguerre, widening its range of applications. Fred'k E. Ives, of the Institute, published the first perfected orthochromatic process. Orthochromatic plates soon appeared in the lists of up-to-date manufacturers.

The processes for multiplication by action of light have sympathized with the general progress of the negative practice, but have not kept pace with it. The direct printing out processes in use from the earliest albumen coated silver chloride paper down through the papers of various names, coated with gelatine or collodion as vehicles, with their dependence on daylight for printing and their subsequent operations, are ante-Daguerrean in principle, and almost anachronisms in this day. The developing papers, with their independence of daylight, and in the Velox-type permitting developing by comfortable gaslight, and, with suitable apparatus for exposure, yielding 5,000 prints per day, seem more nearly up to date.

But all processes with silver are viewed with distrust in regard to permanency. Two processes at least are regarded with more favor in this respect, and are recommended by the National Photographic Records Association of Great Britain for its photographs. The carbon or pigment process, which carries back in principle to the time of Niépce, based upon the discovery of Mungo Ponton in 1839, of the loss on exposure to light of solubility or stickiness by gelatine and other organic substances, mixed with alkaline bichromates. The other, the platinum process dependent upon the reduction of a ferric to a ferrous salt by light, one of the many discoveries of Sir John Herschel, and the reducing action of the latter on a platinum salt also present in the paper. The process, originally patented by Mr. Willis, now free, is simple in manipulation, and yields artistic effects as well as permanent prints. The blue print process, humblest of all, but yielding a larger acreage than all others, also originating with Sir John Herschel, is based on the reduction of a ferric salt, and as practised to-day, also in some degree upon the reduction of a ferricyanide.

But a thought ever present with investigators has been the multiplication of pictures by other than purely photographic methods. Niépce started with the motive of etching plates by means of light for printing. Attempts were early made to convert the daguerreotype into a printing surface. In recent years processes based on the properties of gelatine mixed with alkaline dichromates have been commercially highly successful, as photo-lithography, the heliotype, Woodburytype, swelled gelatine and washout gelatine processes, etc., some capable of rendering all the tones, others restricted to black and white, but none of them meeting the growing demand for typographic blocks capable of rendering the shades of the original. At an early day it was found that by breaking up the shades by a grain imparted to the printing surface in different ways, half-tones could be simulated, and the line screen was one of the methods for so doing. But in none of these methods was there an attempt at what might be termed a discriminating grain, a precise rendering of the shades, as an engraver would do, by lines and dots of varying sizes and separation. In 1891, Frederick E. Ives, of our Institute, patented and conducted commercially a process that might be characterized as ideal in this respect. By it all the tones of photographs and wash drawings could be faithfully rendered by typographic blocks. The testimony most conclusive on this point, perhaps, is the criticism of the art critic of one of the leading dailies of New York, of engravings in a work which called for art of high character. To quote his words in regard to some pictures selected by him as the "finest in the book," he says: "Without detracting from the artist's meed of praise, it may be added that the most remarkable thing about these illustrations is the extraordinary skill displayed by the engravers," and he speaks of the "marvellous delicacy of precision and touch," "power of taking up the theme submitted by the artist," etc., and yet they were soulless photo-engravings by Mr. Ives' purely mechanical process. The blunder of the critic does not reflect on his professional character, but only on his ignorance of the resources of photography. This process has been largely replaced in recent years, for the requirements of the general trade, by the more facile line screen half-tone process, greatly improved by the variation and proper manipulation of the screen and stops employed, and by attention to the optical conditions involved.

Color photography, the dream of every one interested in photography, has seemed to many beset with apparently incompatible conditions, and the unattainable limit of photographic progress. It has none the less, from the earliest period, engaged the attention of the ablest investigators.

A measure of success has been announced from time to time, by Seebeck in 1810, and subsequently by Sir John Herschel, Becquerel, Niépce de St. Victor, Poitevin, Simpson and others. In all cases a difficulty in fixing the pictures has prevented a much-desired general inspection. The following extract from a letter of Sir John Herschel, in 1865, is one of the most favorable accounts: "I received a complete colored spectrum picture from Becquerel several years ago, which is still as fresh in color as when received. The whole spectrum from end to end, if not brilliant, is still distinct. I seldom examine it, and only by lamplight." The more recent process of Lippmann, founded on interference of light, is of great scientific interest, but, if it has a commercial future, has not yet passed its experimental stage. Other less direct processes seem more practicable. The so-called Jolly or McDonough process, dependent upon a taking screen of lines in intimate contact, colored in series red, green and blue, placed before the plate in taking the negative and used in viewing the result, is also short of commercial success. The heliochromic process of Frederick E. Ives, in conjunction with the kromskop, comes nearer the complete realization of reproduction of natural colors, and is commercially available. It requires three negatives simultaneously taken, representative of the Young-Helmholtz-Maxwell color sensations, and three positives simultaneously presented to the eyes in the kromskop, by light through glass or screens (red, green and blue-violet) suitably colored for each. The camera for taking the negatives and the instrument for viewing the positives are ingenious and practicable. Until some process based upon some new material, or new principle, is discovered, this process is likely to hold its present place. Possibly the silver photohaloids investigated by M. Carey Lea may yet lead to the perfect-color process.

The scientific world, hardly recovered from the shock of surprise at Röntgen's discovery, and undecided whether it is dealing with rays or emanations, led by it, seems entering a new and broader field of investigation, almost uncanny in some of its aspects. The terms Becquerel rays, Russel rays, metallic radiations, vaporography and the like are full of import. As stated by Dr. Crookes, "Some bodies without special stimulation are capable of giving out rays closely allied, if not identical with those of Röntgen, and it would almost seem, from the important researches of Dr. Russel, that this ray-emitting power may be a general property of matter, for he has shown that nearly every substance is capable of affecting the photographic plate, if exposed in darkness for a sufficient time." The list of active substances is a long one, to which a recent investigator has added the human body. The rays pass through many opaque substances, and are checked by others. They excite fluorescence. Already they have led to the discovery of a new metal by Madame Curie, and named polonium, possessing 400 times the energy of uranium, which has hitherto held the highest place. It was announced in the morning paper that Prof. Geo. F. Barker has brought with him from Paris, a specimen of the new metal, and we trust we may look for some demonstration of its properties at an early day. This energy seems to be without exciting cause, and without perceptible diminution. If radiant energy, may not perfumes, which have been regarded as material emanations, be of the same character, and the rose emit rays that will affect a properly sensitized plate?

This hasty résumé of some of the leading facts in the growth of a branch of science, the history of which practically begins with that of the Institute, to which the occasion more naturally invited than to a display of its achievements, would find its highest justification in the enumeration of its applications. But a very few must suffice. In scientific investigation the eye has been replaced in so many cases by the camera, for observation as well as record, that we begin to inquire what is left for visual observation. This is not for the relief of the eye, but because the photographic plate has so much wider range in time and space. It is capable of observing the instantaneous, and yet of looking without wearying, but with cumulative effect by the hour to catch phenomena to which the eye, with its best aids, is hopelessly blind. It has even been said by an eminent astronomer, that it has added to observing power as much as the invention of the telescope. It has, in fact, revolutionized astronomy. Beginning with the moon, with which perhaps least has been accomplished, total eclipses of the sun have yielded up long desired information, otherwise unattainable, so that they, by comparison, approach the character of worked-out fields. Automatic daily observations of the solar surface, with the details of its spots, promise data for determining effects upon terrestrial climate. Nebulæ have been discovered, their form, details and conditions revealed, and fainter extensions, vaster than could be conceived, added. Comets have exhibited wonderful transformations, distortions and internal movements utterly undiscoverable by the best telescopes alone. Asteroids so numerous leave the record of their existence in trails upon the plates that, as has been said by Professor Barnard, they are turned adrift again unless they show some striking peculiarity of orbit. Meteors record their paths on which rests the expectation of precise determination of the radiant. Combined with the spectroscope, binaries of shortest periods are detected, variable stars not only discovered, but classified. The surmises of mathematicians in regard to Saturn's rings are confirmed. Runaway stars are caught. The Parisian astronomer that could not catch the satellite of Neptune with his telescope, could see it fixed on his photographic plate.

Photography and the microscope, too, have gone hand-in-hand with a more intimate sympathy even than that between the camera and the telescope. Among the earliest amateurs of highest character was a large percentage of experts with the microscope. It was in the decade following the founding of the Institute that the microscope began to assume something of its present character as an instrument of delicacy and precision. In 1831, the factory of Ross was established, and under the stimulus and coöperation of such men as Herschel, Airy, Powell, and more especially Lister, improvements in the optics and mechanics of the microscope were rapidly made, so that at the discovery of photography, microscopy had an entirely modern aspect, and it recognized at once a new ally. Dr. Draper immediately took micro-daguerreotypes. From this time the improvements in optical appliances urgently demanded by the microscopist were ably seconded by the photographer, and both combined were largely instrumental in occasioning the marked progress in practical optics, which, in turn, reacted to advance photography and microscopy. Even in the days of slow wet-collodion good work was done with the microscope, and even stereo-photo-micrographs were taken by Professor Rood. The rapid dry-plate, sensitive to all or any desired colors, has nowhere contributed more to the advance of photographic practice than with the microscope. It has become to it only less the observing and recording eye than to the telescope. The intimate connection between the microscope and the camera is also well exemplified in the Institute, where the gifted Zentmayer gave the world its best model for the microscope, and the lens which bore his name long filled a place entirely its own in photography, and when the Government placed the administration of the total eclipse expedition of 1869 in the hands of Professor Morton, then Secretary of the Institute, it was unnecessary to seek further for the complete solution of the then new practical optical questions involved in such an enterprise.

In chemistry, Dr. Crookes, by aid of photo-spectroscopy and orthochromatic plates, has added the metal monium to the list, with its characteristic lines far out in the ultra invisible light, in the phosphorescent glow of yttria under molecular bombardment in vacuo. Meteorological science is enriched by photography. It is pertinent to mention the interesting contributions of W. N. Jennings, of the Institute, to the study of lightning discharges, and the work of C. Francis Jenkins in the conversion of a scientific toy into the phantascope, which has found its extension in the kinetoscope, and which earned for him the Cresson medal of the Institute. The kinetoscope, with its miles of photographic films, as exhibited first by our H. R. Heyl, has found applications unanticipated in recording the movements during a solar eclipse and of growing plants, and has gone to the front with the army in Africa. In the industries the applications of photography are of infinite variety in character and importance. It is proposed to furnish cards for the Jacquard loom, and thus make tapestries commonplace. It will furnish water-marks for paper capable of 100,000 impressions. It reproduced the Encyclopædia Britannica at one-third the cost of type. It preserved the valuable MS. copy of Century Dictionary, which was practically uninsurable, in miniature form against loss by fire. It may, in the future, in the same way, find a place to economize shelf-room in our libraries by compressing books that are seldom or never read. Its applications are well known in the copying of inscriptions, even in dark interiors, in the preservation and duplication of valuable documents and papers, in the detection of forgeries, especially by the method of composite photography as developed by Dr. Persifor Frazer, in the furnishing of legal evidence in general, in the detection of criminals, etc. In Canada, 50,000 square miles have been platted by means of the photo-theodolite. In the late war the camera went to the front, and has furnished invaluable records. Apropos to this, it is only necessary to recall Capt. Wise making exposures whilst charging up San Juan Hill. In the present African war it promises to play an important part in reconnoissance through the telephoto apparatus that accompanies the British forces.

In its purely commercial aspects this subject is one of growing importance. The demands, at present great, are rapidly increasing with new applications and expansion of those now in use. Outside of the industries consuming photographic goods there are at least 1,500,000 amateurs in the United States, generally regarded as gross consumers. The industries supplying photographic wants are necessarily of the most varied character. Companies supplying them are continually increasing their plants. It is difficult to get at the amount of business and profits, but the published statement of one company originating in America, now in England and America, announced a dividend of 20 per cent. in December last, with repeated interim dividends, on a capital of $8,000,000. Other companies show similar prosperity. One article, largely consumed, may be particularly mentioned, which America does not seem able yet to produce of best quality, namely, paper, and it is well for manufacturers to remember that in photography only the best of everything is good enough.

Anniversary Meeting of the Electrical Section.

INTRODUCTORY ADDRESS.

By Prof. George A. Hoadley,
President of the Section.

Members of the Electrical Section, Ladies and Gentlemen :

It is especially fitting that this Institute, named in honor of that great American who established the identity of the electric spark and the lightning flash, should take a leading part in the investigation of electrical phenomena and the dissemination of electrical intelligence.

GEORGE A. HOADLEY.

This activity has been apparent through the entire life of the Institute in the addresses and published lectures of its speakers. It is only necessary to refer to the files of the *Journal* to be convinced that the work of the Institute in this direction has been of the greatest value in presenting the advances that have been made both in the theory of the subject and in its practical applications. As these applications were rapidly extending into broader fields it was felt necessary by some members of the Institute to form an electrical section for the more detailed and exhaustive presentation of the work done in these fields, and in December, 1890, sixteen members made an application to be constituted the Electrical Section of the Franklin Institute. Their application was acted on favorably and the section was authorized at that meeting. The meeting for organization was held on January 31, 1891, with an attendance that, both by its numbers and by the qualifications of those present, promised to make the Electrical Section one of the vital agencies of the Institute. This promise has been fully justified by the work done in the section. From the organization of the section to the present, ninety-two formal papers have been presented, the larger number of which have been published. These papers have been presented by men who are experts in their various lines, and have brought to the Institute, as a center of distribution, the most advanced thought on the topics considered. They have also furnished subjects for discussion, and experience has shown that the free and intelligent discussion that a paper inspires is frequently its most valuable feature. The gentlemen who are to speak to us to-night have been important contributors to the growth of the science to which the section is devoted.

It gives me pleasure to introduce the first speaker, Prof. Edwin J. Houston, of Philadelphia, the first President of the Electrical Section.

THE SEVENTY-FIFTH ANNIVERSARY OF THE FRANKLIN INSTITUTE FROM AN ELECTRICAL STANDPOINT.

By Edwin J. Houston, Ph.D.,
Professor of Physics, Franklin Institute.

The seventy-five years that mark the life of the Franklin Institute have been fraught with much for the world's weal. During this time great discoveries have been made, and great inventions born, in nearly all departments of physical science, but in none of the sciences have these discoveries or inventions excelled, indeed, I may say, none have equalled, those of electric science and its allied useful arts. Both of these have taken their place in the front rank of progress, and bid fair to continue to outstrip all competitors in their useful gifts to mankind. It is eminently fitting, therefore, that the Electrical Section of the Franklin

Institute, representing as it does the electric arts and sciences, shall join with others in celebrating the seventy-fifth anniversary of the Mother Institute, in the Convention Hall of the National Export Exposition of 1899.

The wonderful progress of electric science and its allied useful arts, and the marvellous gifts they have bestowed on the world have not, as in the case of many other physical sciences, been spread equally over an extended period of time. The last century and a half will take in very nearly all the discoveries and inventions made in electricity; the last century will include by far the most important of these discoveries and inventions; the last half a century, the most valuable and useful, and the last decade and a half, the period of their most extended commercial applications.

EDWIN J. HOUSTON.

Our Institute, founded as it was in 1824, began its existence about the time when electrical activity was markedly increasing, existed during the time of its greatest growth, and still exists at the close of that decade and a half when the commercial applications of electricity have assumed such grand proportions. It is fitting, therefore, that we should inquire both as to how well our Institute, devoted as it is to science and the mechanical and useful arts, has availed itself of the advantages of living in an age of such marked mental activity; and as to what share it has had in the development and application of electrical science.

There is, in every age, a mental horizon which forms the limits of man's actual knowledge. Within this horizon all physical phenomena are readily assignable to their proper causes. Beyond it, other phenomena, discoverable only by the prophetic glance, are too dimly seen to be ascribed to known causes.

In the electrical field this mental horizon was for a long time extremely circumscribed, and even when some progress was made and the horizon extended, obstacles to further progress would loom up, offering apparently insurmountable barriers to further extension. Fortunately, one by one these have been swept away, and the horizon of possible conquest, by unwearying research, has been so greatly extended that, in the public estimation at least, there is little that electric science cannot accomplish.

For thousands of years after his creation man was absolutely blind to the existence of any electric force. Although this mighty power was in operation all around him, in the lightning flash, the Northern light and other physical phenomena, yet he remained practically ignorant of its presence, until Thales, some 600 B.C., discovered the curious properties acquired by a bit of rubbed amber. Even then the electric horizon long remained relatively limited; for, with the exception of an unimportant observation by Theophrastus, about 321 B.C., it was practically more than 2,000 years before any further advance was made into the great unknown land whose shores were thus first dimly discerned. Not until 1600 A.D. had Gilbert and others discovered that many other substances than amber acquired similar properties when subjected to friction. It is true the Chinese were reputed to have been acquainted with the directive power of the lodestone, and to have applied it to practical ends, as early as 2600 B.C.; it is true that some little extension of magnetic knowledge had occurred during the next thousand years or so, and that some little advance had been made in magnetic science by Hartmann, in 1544, and Norman, in 1576, in the discovery of the dip of the magnetic needle. But the intimate relations existing between electricity and magnetism had not yet been discovered, and, consequently, this knowledge failed to influence the limits of the electric horizon.

Before discussing the part played by our Institute in the world's progress in electric science, let us inquire briefly as to what general principles had been discovered at the time of the birth of the Franklin Institute, in 1824. The extent of this knowledge was very limited. Although from the standpoint of that time—1824—this progress appeared to be wonderfully great, yet, compared with what is now known, it was exceedingly small. Reviewing it with necessary brevity, we find that, in addition to the work of Thales, Theophrastus and Gilbert, already recited, Guericke and Hawksbee had produced, in 1675 and 1700, respectively, fairly good frictional electric machines, and that Newton, in 1675, had discovered that electrification imparted to one side of a glass plate produced electrification on the opposite side. No great discovery had been made, however, until Von Kleist, in 1745, invented the Leyden jar, the early type of electric condenser.

This memorable discovery gave an impetus to the study of electricity, which resulted in a fairly considerable advance. In 1752, Franklin, outrivalling Prometheus, had robbed Jove of his thunderbolts, and with that national characteristic of turning all knowledge to every-day use, had shortly afterwards constructed the first lightning rod. Then, excepting the discovery made by Æpinus, in 1759, and Canton, in 1760, of the phenomena of pyro-electricity or electrification produced in certain crystalline bodies by unequal heating, a period of comparative rest followed, until Galvani and Volta made their famous discoveries in 1786 and 1796, respectively, the former, in connection with the frog's legs, and the latter with the voltaic cell or battery.

Volta's invention of the voltaic cell gave a marked impetus to electric investigations, by reason of the means thus afforded for readily producing electricity, and the nineteenth century opened auspiciously for electric science. In 1800, Nicholson and Carlisle effected the decomposition of water by a current from a voltaic pile, and, during the same year, Henry of Manchester similarly effected the decomposition of sulphuric and nitric acids. Nor did the advance stop here. In 1807, Davy made his immortal discovery of the compound nature of the alkalies, and produced metallic potassium by electrolysis, and shortly afterwards extended his discovery by demonstrating that all the earths and alkalies also compound substances. In 1807, he publicly demonstrated the illuminating power of the carbon voltaic arc. Finally, in 1820, just four years prior to the birth of our Franklin Institute, Oersted demonstrated the long-suspected relation between electricity and magnetism, and thus swept away another great barrier to advance.

In considering the part played by the Franklin Institute in the world's progress in electricity during the seventy-five years of its existence, it will be impossible, in the brief time allotted to this address, to make any attempt to trace, or even to call attention to, the individual work undertaken by its members, in the domain of either pure or applied electric science. Such work has been both varied and valuable, and will be found in the *Journal of the Franklin Institute*, in the reports of its various committees, in the transactions of learned societies, or in periodical literature. It will, I believe, be more profitable to employ our time in pointing out the aid our Institute, as a whole, has given, and the contributions she has made, to the general advance in electric science that has taken place during this term. And this, indeed, will be the preferable course, since it is the work of the Institute as a whole, and not of its individual members, in which the public is interested in this, the seventy-fifth year of its existence.

Little did those fourteen men, who, in 1824, organized the Franklin Institute, appreciate the importance of the work they then inaugurated. But, fortunately for its progress, none of the essential requisites for success were absent; the originators were eminently capable men; a great public need existed for the kind of work inaugurated, and its growth was intelligently directed; naturally, therefore, the Institute continued to expand until it assumed the fair proportions it possesses to-day.

There is an enthusiasm begotten of comradeship. When men of similar interests associate themselves together for carrying out any work, that work is not only better carried out as a whole, but the individual workers labor more earnestly and intelligently. But, besides this enthusiasm bred of numbers, each worker, strong in some particular direction, complements or fills out weak points in his fellow-workers. The germs of ideas that might, perchance, have slumbered and died, if selfishly guarded by their originators, blossom out into valuable inventions and discoveries in the enlivening environment of mutual work. It is for the same reason that class study is less fatiguing than individual study, and is, moreover, generally more remunerative, since the errors of others often prevent the continuance of errors in ourselves, and the removal of their difficulties aids in the removal of our own. And even when one has reached the necessity to specialize and pursue his studies alone, it is an advantage to come every now and then into mental contact with others of similar, if not identical, pursuits, not only to have enthusiasm enkindled, but also to readily exchange ideas, solve doubts, suggest lines of research, and encourage each other to further advance in the line of his special studies.

The solitary recluse student, who limits his companionship strictly to his own thoughts, may have the good fortune to avoid errors and make fair advance in his special studies, but that advance will be both surer and more rapid if he will but admit into his mental world either the thoughts of others as expressed in books, or, still better, thoughts fresh from the living lips of those who will afterwards publish them in printed characters. But it matters not whence the student gathers knowledge; its value to mankind may be gauged by the extent to which it is freely given to his fellow-student.

Unfortunately for the world's progress, the characteristics of the miser are not limited to the selfish hoarding of money or other forms of material wealth. The mentally rich are often more reprehensible in hoarding for their exclusive use the little store of knowledge they are foolish enough to believe can be kept exclusively their own; or, if they share such knowledge at all, it is only with little exclusive coteries of their own, for self-glorification. These pigmy mutual admiration societies, whose members are occupied mainly in sounding each his own praises and magnifying his own achievements, aid but little in the general progress of the world. Their mental world, in their belief, is so far uplifted beyond that of the rest of mankind that they are unwilling to have it enter into their lives, and when they have anything worth publishing they too often phrase their discoveries in language unintelligible save to those belonging to their exclusive set.

Associations formed of such men never have and never will develop phenomenal growth. What discoveries are made by any of their members will practically remain a dead letter. It is no excuse to plead that certain lines of study are so abstruse that it is impossible to describe them so as to permit any but those especially skilled even to faintly comprehend, much less to thoroughly grasp them. This is not true. An idea, no matter how complex, if thoroughly understood, is capable of analysis into its component ideas, and these, necessarily elementary, are readily susceptible of being so phrased as to be thoroughly grasped by others. He who assumes that his ideas are so far removed from the range of the average intellect that it is useless for him to attempt to appeal to it, and who adopts a mysticism in giving them to the public, not only renders such publications comparatively worthless, but even renders himself liable to the suspicion of but vaguely comprehending the ideas himself.

Some apologists for exclusiveness in scientific research have endeavored to erect a barrier between pure and applied science. While, of course, a distinction necessarily exists between the two, yet the lines of demarcation are by no means sharp, and it is worse than foolish to attempt to keep them apart. Ideas, evolved by the so-called pure scientists, that are incapable of being put to practical use, are shadowy and unsubstantial, and unworthy of being ranked as great ideas.

Another unsound contention of these scientific exclusionists is that the investigator is degraded by actually putting his discoveries into operation for the benefit of his fellow man. Fortunately for the world, these ideas were not shared by such grand investigators as Morse, Henry and others of their type. Indeed, it is impossible for one to become a great physical investigator who does not continually subject his theoretical deductions to proof by actual trial. It is folly to maintain that he who aims at discovering the laws of nature can make any marked advance without constantly interrogating her by actual experiment. When certain deductions have been made and a generalization reached, if the investigator fails to test the correctness of such investigation by trial, he will, most probably, fail to achieve further advance into the unknown. Conclusions based on laboratory experiments carried on by minute quantities of material and comparatively feeble forces, and those conducted on a commercial scale, are perhaps equally reliable. But no one can deny that the most conclusive test of the correctness of any general physical law is obtained by commercial results rather than those of the laboratory. When a machine embodying the principles of a great invention has been reduced to a drawing, much has been done. But such a machine cannot be regarded as actually completed until it has been put into gross material and employed in doing actual work.

The magnificent exhibits of the National Export Exposition that are to-day offered for our inspection have been rendered possible only by the carrying out of such lines of action. They are the natural fruits of great ideas embodied in practical working machines or processes.

The Franklin Institute has achieved the marked growth it possesses to-day because its work has possessed the following characteristics, viz.:

(1) Co-operation of work undertaken jointly by men learned in books and men learned in things, a great working brotherhood of theory and practice.

(2) The widest possible publication, in language intelligible to all, of ideas born in its midst, or presented to it for consideration.

(3) Reduction to practice, by subjecting all discoveries and inventions to the test of actual, every-day use, thus carrying out the purpose for which it was incorporated; viz., "The Promotion and Encouragement of Manufacture and the Mechanic and Useful Arts."

For the proper carrying out of these characteristic types of work the Institute has its regular monthly meetings, its valuable library of reference, its "Memorial" electric library, its historical collections, its various sections, its popular lectures, its Committee on Science and the Arts, its drawing school, its *Journal of the Franklin Institute*, and last, but by no means least in value, its exhibitions. It is far from my purpose to refer to these in detail. They are enumerated merely to permit you to readily see how ample are the means the Institute possesses for carrying on its work along the directions already outlined.

The Franklin Institute has carried on important work of the above-named characteristic types in all the physical sciences. But, as representing the Electrical Section, we are to-night mainly interested in electric science, and in this direction the work of the Institute has been of a character of which we may justly be proud. Through all its characteristic types of work it has contributed freely to advance in electric science, and we might profitably examine in detail contributions of each of these agencies did time permit. Without any desire to belittle the work of the other agencies, I will ask you to examine briefly with me one only of the most conspicuous of these; namely, that of the International Electric Exhibition of 1884, and this, I think, we are justified in doing, since this particular class of work was strictly limited to electrical devices and applications. I might, indeed, well expend the time in considering the work of our Electrical Section, but, since the exhibition was held at its suggestion, I think a consideration of the work of this exhibition will suffice.

The Electrical Exhibition of 1884 assumed its international character by virtue of an Act of Congress approved February 26, 1883. Like the present National Export Exposition, it was located in West Philadelphia. The conditions were especially favorable for the holding in this country of an exclusively electrical exhibition. The movement favorably attracted the attention of electric scientists and of manufacturers of electrical apparatus in all parts of the world, so that the exhibition contained electrical devices, apparatus and machinery from all parts of the world. Every branch of electric science contributed some exhibits of the most interesting type; namely, working exhibits, interesting as showing the mastery that had been achieved in those branches of electric science that had produced such exhibits, thus putting the electric forces to every-day work. Besides, there were interesting historical exhibits.

The extent and variety of the different exhibits excited wonderment in the minds of the many visitors. To those unacquainted with electric science, a wonderment that it covered so extended a field; to those fairly acquainted with the achievements of electricity, a wonderment that these achievements so far exceeded in number and variety what they had heretofore credited it with ; to those from distant countries, or distant parts of this country, a wonderment that other countries, or other parts of this country, had so far advanced in their products ; to capitalists, a wonderment that so promising and varied a field was offered for profitable investment ; to those of an inventive mind, a wonderment that so much room still existed for improvements in existing methods of application, or for work in new directions. The environment of the exhibition favored unusual electrical growth, and subsequent facts amply show that the expectations for such growth were fully realized.

True to its general policy of educating the masses, the authorities of the Franklin Institute proceeded to utilize the occasion to increase the knowledge of its members and visitors. Besides the numerous working exhibits, it collected an admirable historical exhibit, showing the gradual growth of electric apparatus and appliances ; it began the collection of a valuable "Memorial" electrical library, it gave to the visitors the names of the different apparatus exhibited, by suitably placed cards, and for further information referred the visitors to printed placards describing the apparatus in detail—placards that were afterwards amplified and issued in the shape of primers of electricity; it had courses of public lectures on electrical topics delivered by eminent scientific men, as well as special lectures prepared for the children of the public schools. The exhibition thus became a great school for all sorts, conditions and ages.

During the progress of the exhibition, and called together by reason of its existence, there was assembled a United States Electrical Commission, appointed by the President of the United States under authority of an Act passed by Congress, May, 1884. Under this authority the Commission conducted a National Conference of Electricians, wisely including in its invitations to such conference both men eminent in electrical science and men eminent in the electric arts in this and in other countries.

It was practically in the International Electric Exhibition of the Franklin Institute that the great American Institute of Electrical Engineers had its birth. This great body of eminent electricians that has done so much to create and direct electrical science, both in this country and abroad, may, strictly speaking, be claimed as the child of the Franklin Institute, and, although it is to-day an independent and separate body, yet the friendly relations still existing between the two institutes may be inferred from the fact that out of the twelve presidents of the American Institute of Electrical Engineers, five have been selected from members of the Franklin Institute, and that during the nearly fifteen years of the existence of the American Institute of Electrical Engineers, eight of these years it has been presided over by a member of the Franklin Institute.

It is difficult to properly estimate the beneficial effects produced on the progress of electric science and its allied useful arts by the mere coming together of such bodies of men in an environment so essentially electric. The wonderful possibilities of electricity, though generally appreciated before the time of the exhibition, were then more clearly seen, and the foundation was laid, certainly in this country, and, most probably, in other countries as well, for that marvellous growth in the commercial applications of electricity which has taken place since the time of the exhibition.

It is far from my desire to claim for this special work of the Franklin Institute that it was the sole influence that determined this subsequent phenomenal growth. It is sufficient if I have shown that it was a directing cause. I certainly feel justified in claiming that never before in the history of this country, and, perhaps, never since, has so much been done to further and foster the electric arts than has been accomplished, both directly and indirectly, by the International Electric Exhibition of 1884, undertaken under the auspices of the Franklin Institute of the State of Pennsylvania.

In inquiring as to the part our Institute has taken in the advances that have been made in electric science during the past seventy-five years, let us briefly consider some of the more important that have been made during this period. We are to-day practically at the beginning of the twentieth century. The seventy-five years we are about considering practically constitute the second, third and last quarters of the nineteenth century. While we can conveniently consider the advances made during this time as the second, third and last quarters of the nineteenth century, yet it will be advantageous to consider the last quarter, especially with reference to its last decade and a half. In other words, we will divide the three-quarters of a century into two parts, viz., the sixty years prior to 1884, and the fifteen years subsequent to this time. I do this designedly to call your attention to the marked influence the Electrical Exhibition appears to have had on the electrical activity of the entire world; for, we will find that by far the greater bulk of era-making applications reached their most extended commercial extension after 1884.

Of the discoveries made prior to 1884, let us first briefly consider those of the second quarter of the nineteenth century. Oersted's great discovery was almost immediately followed by Ampère's valuable researches, so that, quite naturally, the beginning of this period was noted for the production of the electro-magnet, in substantially its present form, by Sturgeon, in 1825, and by Henry, in 1828. The wonderful extent to which electro-magnets enter into the structure of nearly all modern electric appliances will give some idea of the value of this invention.

But another discovery was made in this quarter of the nineteenth century that was even more important than that of the electro-magnet. I refer to Faraday's immortal discovery, in 1831, of magneto-electric induction. This was the converse of Oersted's discovery of the production of magnetism from electricity, since it showed how electricity could be produced from magnetism. Faraday demonstrated that when a coiled keeper was suddenly separated from a permanent magnet a spark was produced; that when a permanent bar magnet was suddenly thrust into or withdrawn from a coil of wire, an electric current was set up in the coil, flowing in one direction on the insertion of the magnet, and in the opposite direction on its withdrawal. He also laid the basis for the subsequent invention of a practical dynamo-electric machine by demonstrating that an electric current was produced in a copper disc by rotating it between a pair of magnet poles. All these in 1831.

Faraday's discoveries soon led to the production of fairly efficient magneto-electric machines, the forerunner of the modern dynamo. Such machines were produced by Dal Negro and Pixii in 1832, by Saxton in 1833, and, subsequently, by Clarke, Ritchie, Jacobi, Sturgeon, Wheatstone, Cooke, Nollet, Von Malderen, and many others. In 1854, Hjorth had discovered, and practically applied, the reaction principle, whereby the currents generated in the armature coils were utilized to strengthen the magnetism of the field, the armature and the field, thus mutually aiding each other until the machine "built up," or became capable of producing its full working current. This principle was independently discovered, either partially or completely by others, especially by Varley, in 1867, and independently by Werner Siemens and by Wheatstone in the same year. Numerous inventions followed, the dynamo of the third quarter of the nineteenth century, reaching its practical culmination in 1870, in the then famous generator of Gramme.

Naturally, the invention of the electric motor also followed Faraday's discovery, so that this important application of electricity also belongs to the second quarter of the nineteenth century. As early as 1831, Henry had suggested and described methods for utilizing electro-magnetism as a motive power. Dal Negro made similar suggestions in 1833, and Jacobi in 1834, and Page in 1850, had produced operative electric motors.

During this period the electrolytic power of the current had been practically applied by Jacobi, who, in 1838, had invented the art of galvanoplasty or electrotyping, whereby the cold casting of the metals might be effected by electrolytic deposition. Elkington and Wright, at a somewhat later date, had made important applications in the same direction. It was also during this period that Ohm, in 1827, made his great generalization concerning the flow of current in the electric circuit.

Another exceedingly important invention of this second quarter of the nineteenth century was that of electro-magnetic telegraphy, rendered possible by the production, in 1836, by Daniell of his constant voltaic cell. Consequently, the next year, 1837, was memorable in the annals of telegraphy, since during it Morse in America, Steinheil in Munich, and Wheatstone and Cooke in England, produced electro-magnetic telegraphic systems that are substantially similar to those employed to-day. Ever since this date telegraphy flourished, and in 1858, near the beginning of the third quarter of the nineteenth century, Field had accomplished the laying of the first Atlantic cable.

The early part of the third quarter of the nineteenth century was largely occupied in telegraphic matters. The suitability of gutta-percha for the insulation of submarine cables was recognized, the phenomena of electric charge in telegraphic wire carefully studied, the existence of earth currents demonstrated, and various improvements made in telegraphic apparatus. This part of the period culminated in the laying of the Atlantic cable in 1858.

It is interesting to note that this laying of the Atlantic cable, requiring, as it did, the investment of considerable capital, necessitated a more accurate knowledge of electric laws, and so laid the foundations of electric engineering, which may properly date its origin from this time. It is true that frequent efforts had been made before 1858, to introduce the electric light on an extended commercial scale, and that Staite, Petrie, Foucault and many others had produced fairly operative lamps, but the electric current, as furnished by voltaic batteries, was too costly, and these efforts signally failed.

The last quarter of the nineteenth century, as you are all aware, has been a period of marvellous activity in electric science. The excellent dynamos of Gramme, Siemens, Halske, Hopkinson and others in Europe, and of Brush, Weston, Thomson-Houston, Edison, Crocker-Wheeler and others in America, assuring, as they do, the production of cheap current, have rendered possible many extended commercial applications of electricity. For example, another attempt, and this time a successful one, had been made for the extended commercial introduction of electric lighting. Improvements have been made, by the above and others, in generators and lamps for arc and incandescent systems, both by direct and alternating currents; and the commercial applications of electric lighting that exist to-day, at the close of the last quarter of the nineteenth century, have assumed enormous proportions.

As we have seen, improvements in arc lighting were extended over a comparatively long period of time. The same is true of improvements in incandescent lighting. As early as 1845, King had invented a lamp whose light was due to the electric incandescence of a small pencil or thin plate of carbon in a Torricellian vacuum. Roberts, in 1852, had produced a light by incandescing conductors in a high vacuum. More recently these have been followed, among numerous others, by Lane-Fox, Swan, Maxim, Sawyer-Mann and Edison, especially the latter, who have produced the efficient incandescent lamps of to-day.

Near the beginning of the last quarter of the nineteenth century, in 1876, another era-making application of electricity was accomplished by Bell in the speaking telephone. Bell's invention was an improvement of Reis' prior telephone of 1861. The telephone has, during the latter part of this period, attained a marvellous growth, and is to-day a formidable rival of the ordinary telegraph.

The application of the direct electric current to systems of street-car propulsion is another direction in which enormous progress has been made during the last decade and a half. But probably in no direction has progress been so great as it has in the field of alternating electric currents. Though known long prior to 1875, yet their marked extension commenced at a comparatively recent date. Short as this time has been, it has sufficed to almost create a new science within a science. Electric power transmission on an extensive scale has also been rendered possible by means of alternating-current apparatus.

As to electrical progress since 1884, the time is so recent, a mere decade and a half, that the prominent developments are still fresh in your minds, and might, therefore, be left to what has already been mentioned in connection with the last quarter of the nineteenth century. But so much has been accomplished during this time, and the part our Institute has played, especially in its International Electrical Exhibition, in determining and shaping this progress has been so important, that we can well devote some time to a consideration of the most important of these developments. If the nineteenth century may be referred to as the Age of Electricity, its last decade and a half may pre-eminently be regarded as the Age of Commercial Electricity, the time during which electric arts have reached their highest development. Indeed, this trait may possibly be the characteristic feature of the twentieth century, so far as electricity is concerned.

Taking up the commercial applications of electricity which have attained phenomenal growth during this time, without strict reference to their chronological order, we will first consider street railways. The replacement of the lumbering stage and omnibus by the horse car, on the tramway or car track, and the partial replacement of the latter by the cable car had already occurred. It was about 1884 that the peculiar fitness of electric traction for the work led to its extensive introduction, and, so rapid has been its adoption since that time, that to-day there is scarcely a horse car to be found in any of our large progressive cities or towns.

Electric traction is pre-eminently one of the commercial applications of electricity that have offered an attractive field for the remunerative investment of a vast amount of capital. Some idea of the extent of this investment may be obtained from the fact that, in the United States alone, the gross receipts of some 222 street railways reached, in a single year (1898), the vast sum of about $128,000,000. Of these 222 roads, some 26 had annual gross receipts of $1,000,000 or over; some 20, annual gross receipts of between $500,000 and $1,000,000; some 58, between $100,000 and $500,000; some 62, between $50,000 and $100,000, and the remainder between $25,000 and $50,000.

Although alternating electric currents, transformers and polyphase motors have been known long prior to 1884, yet their extensive commercial application has been subsequent to that date. The comparative simplicity of the armatures of polyphase motors, their long life under continual use, and their powerful starting torque give them advantages over continuous-current motors that the commercial world has been prompt to recognize. Moreover, the readiness with which alternating electric currents, in connection with the modern transformer and polyphase motors, lend themselves to the economical transmission of energy over considerable distances, has caused the system to be almost exclusively employed for electric power transmission. In addition to this, we may add the extensive practical application of alternating currents to electric lighting, both arc and incandescent, and to heating, welding and some forms of electric furnaces.

The following estimate as to the total production of alternating-current apparatus in the United States in 1898, will give some idea of the extended use of this type of electric apparatus, viz., total estimated production of alternating-current generators and motors, 120,000 horse-power; of transformers, 750,000 lights capacity, and of meters, 750,000 lights capacity.

Although, as we have seen, the storage battery had its origin in Plantè's secondary battery of 1859, it was not until 1884 that it was capable of extended commercial application. As it exists to-day, its efficiency and length of life under the requirements of actual use have permitted it to come into very extended every-day use, not only for general purposes, but also in electric light and power stations for the purpose of adding to the total output at the time of maximum load. Another use for the storage battery, that promises great developments, is its use for the propulsion of automobiles. The growth of this comparatively new branch of electric science bids fair to assume enormous proportions in the almost immediate future.

Extended commercial applications of the telegraph and the telephone, especially the latter, have been especially marked since 1884. The fundamental apparatus of both the electro-magnetic telegraph and the speaking telephone were invented long prior to this date; the telegraph in 1837, and the telephone in 1861; but while the extended commercial application of the telegraph was made long prior to 1884, Field having laid the first Atlantic cable in 1854, the extended commercial application of the telephone has been since that time. I will permit you to infer its marvellous growth from the case of a single city, say New York, where, in 1895, there were about 10,000 telephone stations. In August, 1899, there were in the neighborhood of 33,000 stations, thus rather more than trebling the number in less than half a decade. New York City to-day, that is, the old city together with the boroughs of Manhattan and the Bronx, is said to have more telephones than London and Paris together.

The practical commercial application of electro-magnetic waves has been accomplished since 1884. The existence of electro-magnetic waves had been recognized long before this time. As early as 1842, Henry of Princeton observed that steel needles placed in the cellar of his house, were magnetized by a condenser discharge in an upper room. Maxwell, in 1864, had announced his hypothesis as to the practical identity between electro-magnetic radiation and ordinary light, and in 1888, Herz, by employing the principle of resonance, had corroborated Maxwell's hypothesis, showing that electro-magnetic waves possess practically the same velocity as light. Finally, Marconi and others have applied these principles to the transmission of intelligence, and wireless telegraphy is being put to actual use; and although the probabilities of its ever becoming a formidable rival of existing telegraphic systems are somewhat remote, yet it possesses great future possibilities.

The so-called X-rays form, most probably, another variety of electro-magnetic waves that has come into extended commercial use since 1884. Their peculiar behavior as regards many substances opaque to ordinary light (itself a form of electro-magnetic radiation) has rendered them of great practical value in connection with photography, for accurately locating the position of certain foreign substances in the human body, as well as indicating abnormal conditions of its tissues, organs, etc. The Wehnelt interrupter, which has been of so great service in connection with the induction apparatus used in X-ray work, has also been introduced since 1884.

Electric lighting, both arc and incandescent, has shown an enormous increase in actual use since 1884. The number of electric lighting stations now existing in the United States is by no means limited to the number of cities and towns in this country. In nearly all large cities there are separate stations provided for different localities. Moreover, the number of isolated plants in all our large cities and towns is considerable, some of which, in the case of tall office buildings, are almost sufficiently large to equal in their output that of moderately large central stations. For example, in the city of Boston there are, according to a recent report, no less than twenty-nine generating stations and 195 isolated plants. The dynamos in operation have a total capacity of 424,443 incandescent lamps and 10,094 arc lamps, which, including some 7,070 electric motors, require some 90,382 horse-power of boilers and 66,774 horse-power of engines.

The part which electricity, mainly since 1884, has come to play in our lives in great cities is manifold. We light our streets, our public buildings and our houses with it, drive our street cars, transmit messages by telegraph and telephone, operate annunciators, protect our buildings by fire and burglar alarms, drive motors, rotate fans, bring cheap power from distant waterfalls to our doors, install electricity for varied purposes on our war vessels, and employ it in many other ways, which will doubtless suggest themselves to you.

This extended commercial use of current calls for the manufacture of much apparatus. Looking over the annual report of a single large company in this country, we find that for the year ending January 31, 1899, the total sales, as billed to customers, amounted to more than $17,260,000, and this, good, profitable business, the calculated direct profits amounting to more than $2,500,000. Some idea of the business done by the company in electric lighting may be inferred from the fact that during this term the orders for incandescent electric lamps reached 8,400,000 lamps!

The manifold uses of electricity to-day in our modern cities mean the employment of a vast number of electric wires and conduits, both overhead and underground. Take, for example, the city of Boston. There are, in this city, according to a recent report, of underground wires alone, 726,997 feet of conduit; 3,469,011 feet of duct; 5,427,482 feet of cable; 167,751,793 feet of single conductor in cables.

The enormous demand for electric apparatus has not been without its effect on the price of copper, which has advanced materially during the past five years, rivalling even the increase in the price of zinc, lead and iron.

Such is the record of the seventy-five years during which the Franklin Institute has existed. That it has exerted a marked influence on the extension and application of electricity, not only, as I have endeavored to point out, by its great International Electrical Exhibition of 1884, but also through the many other kinds of work by which it endeavors to extend electric science and ensure practical applications of the same, I believe none will question. Regarding to-night the growth attained by electric science during the nineteenth century, we may well exclaim with Morse, "What hath God wrought?"

THE INFLUENCE OF TECHNICAL SOCIETIES IN PROMOTING THE PROGRESS OF THE ARTS.

BY RALPH W. POPE,
Secretary of the American Institute of Electrical Engineers.

When we consider the vast strides made during the century in practically every branch of applied science, or even the advances made within the memory of the youngest among us, it is not now difficult to realize that seventy-five years ago there existed a field for the Franklin Institute.

RALPH W. POPE.

That it survived, and is now active along the lines projected by its founders, proves, beyond question, the wisdom of those whose memories we unite in honoring to-day. A record of seventy-five years devoted to the encouragement of art and science is most enviable, and whatever may happen, no break in its continuous career should ever be permitted.

Here has been maintained, through peace and war, through prosperity and adversity, a forum where every struggling scientist and every hopeful inventor might meet with the encouragement that stimulates, or that kindly criticism which frequently leads to well-merited success.

It has been the good fortune of the Franklin Institute to watch beside the cradle of the infant steam: to observe the gradual development of this mighty force, until upon its foundation there has been erected the new and gigantic electrical industry which through ignorance is frequently considered its rival and possible successor. The builder of the steam engine has seen no wave of prosperity which will be so enduring and so satisfactory as that which has followed in the wake of the electric generator and motor.

While the utilization of water power for the generation of electricity is important, nature has arbitrarily confined this practice to a comparatively few and limited districts, so that to-day, and, so far as we can predict, in the future as well, the steam engine as a prime mover is without a rival. The power having been developed, what may we not accomplish through that unequalled distributing agency, the electric current?

Just as the steam railroad had entered upon its useful career, the world was startled by the successful invention of the electric telegraph, the first example of instantaneous transmission of power to a distant point. Still mankind had lived and multiplied, nations had arisen, cities had been founded and fallen into decay, great battles had been fought, literature and the arts had flourished. The steam engine, however, was unknown, and the telegraph was but a dream.

Even to-day, surrounded, as we are supposed to be, with every possible convenience and luxury, men and women may be found living happy and contented lives who have never sent a telegram, nor seen an electric car. Consider Alaska, until recently without a railroad or a telegraph, where only hardship, famine, disease and possibly death were reasonably certain; where men have fallen in exhaustion overladen with gold, which brought no food where food did not exist. But men with stout hearts and sturdy muscles have left comfortable homes and lifelong friends to grapple with cold and hunger in order to wrest from nature's secret storehouses the golden nuggets which have been hidden for ages in that hitherto almost inaccessible spot.

We have assembled to-day, however, to eulogize the influence of science upon the advance of civilization. We are here to assert that the world is growing better, even as we believe it is growing more comfortable. Brief as may be our pilgrimage, we live longer, or rather, as we journey through life, our experience is greater. The world's history, thanks to the press and the telegraph, is spread before us each day as important events occur. The thread of sympathy with the distressed entwines the hearts of every nation, and again, in the words of the Psalmist: "Let the earth rejoice," for is it not known throughout all lands that Dewey has received the grandest welcome of ancient or modern times?

Even this great outburst of patriotic enthusiasm is a tribute to scientific research. Without the aid of steam or electricity the concentration, within so short a space of time, of such a multitude from all portions of the country upon Manhattan Island would have been an impossibility.

Step by step, during this wonderful nineteenth century, we have watched the growth of these marvellous achievements until we have been educated to the belief that there is practically no limit to the stride of invention. When we consider the perfection of modern mechanical methods, however, the results obtained in early days should excite our admiration.

Fifty years ago the steam locomotive had a speed record of a mile in a minute, and the general improvement in schedule time since that period has been largely due to a more perfect track and longer runs rather than to any radical change in the original machine. With the same machinery used fifty years ago the skilled Morse telegrapher could do as rapid work as he can to-day.

In both cases the original idea appears to us now as exceedingly simple. Subsequent perfection in details has been a process of evolution. During all this time a small army of inventors had grappled with the problem of a typesetting machine, and not until within the last ten years has success been attained. The germ of a great invention is a tender plant. It must be nurtured with extreme care. It is for the encouragement of these early steps in the advancement of an art that this institution exists.

Once success in an art is attained, popular enthusiasm will soon place it beyond the reach of adversity. Too frequently the original inventor, and even the sanguine financial promoter, fail to reap their just reward, but the idea lives, and the people are benefited by the improvement.

Notwithstanding the important bearing which science and mechanics have upon our national progress as well as our personal comfort and satisfaction, your attention is directed to an apparent omission in our educational system. It is quite certain that scientific and engineering societies would be more generally appreciated and more heartily supported, if students were more thoroughly trained at an early age in elementary physics. They should also have an opportunity for practical work in wood and metal with good tools. If they have no inclination toward work of that character, the experience will do them no harm, while in the majority of cases the knowledge thus gained will be of great use to them later in life.

Within the past few years more attention has been given to manual training, but there are still, no doubt, thousands of schools in the country where there is no attempt to master even the simplest scientific facts.

As I travel daily between New York and my home at Elizabeth, the Staten Island shore is plainly visible. Years ago a vessel laden with oil took fire and was beached at the northern end of the island. The oil continued to burn for a day or two, and the novel sight naturally attracted the attention of the passengers. Directly in front of me two intelligent-looking gentlemen laid aside their morning papers for a moment and began talking about the fire. One of them said he supposed that what they saw was the burning oil floating on the water. "I know oil will float on the water," said his companion, "but I'm not sure whether it will float when it is in barrels." "Neither am I," was the reply. Here were two men, either of whom knew that oil would float on water, and either of whom was probably certain that a barrel would float, but whether the two combined would float or sink was beyond their comprehension.

It is not necessary that we should know what electricity is, or what gravitation is, or account for the existence of what is known as permanent magnetism. We can, however, readily master certain laws based on scientific facts. We can assure ourselves that, under certain conditions, certain results will be accomplished. There is no reason why these facts should not be thoroughly grasped in childhood.

There are no toys so interesting to the young as what are known as scientific toys, and if parents are neither willing nor capable of teaching their children these important truths, we should see that they are generally taught in school. The prevailing ignorance in such matters is responsible for the existence of a class of alleged inventors who devise schemes for obtaining money under false pretences. Most of us are familiar with examples of this fraudulent practice, and Philadelphia has been a favorite field of operation. The notoriety attained by such impostors has reacted upon honest inventors, who frequently lack capital to develop their ideas. There is but one safe course for an innocent but honest investor. He should seek the advice of an experienced and competent expert familiar with the field which is to offer a market for the invention. If he is not financially able to pay for such an opinion, then he is not in a position to take the risk of a doubtful investment.

It is too frequently the case that the investment is made first, and the expert called in after thousands of dollars have been squandered. There is always an air of suspicion hanging about these questionable enterprises. Some vital link is a profound secret. There is a mysterious chemical compound or some unaccountable manifestation of force casually referred to by the exploiter that should place every investigator on his guard. It is not necessary that an expert should be expected to explain a manifestation when he is morally certain that something is hidden from him.

On the other hand, it is not always well to place too much confidence in the statements of the really honest inventor. His mind may be biased by his enthusiasm, and without intent to mislead, he may neglect to call attention to certain facts which would detract from the usefulness of his improvement.

Having guarded all these points, however, there is still another test to which an important invention may be subjected. Let it be exhibited and accurately described in open meeting before such a society as the Franklin Institute or the American Institute of Electrical Engineers.

When the subject is thrown open for discussion, the demonstrator must have his wits about him. He will find that flaws exist which he never dreamed of. He will learn that even if his apparatus works, there may be a dozen reasons given why it ought not to work. He will be surprised to find that the cost will be so much greater than under existing conditions, that no one will have anything to do with it. He should not be discouraged by these slighting remarks. There are always people who think that anything new is not good, and anything good is not new. If his machine or process works, he can disregard the reasons why it should not. If it is a decided improvement, he should remember that good things are frequently expensive. People do not continually eat "pork and beans" because experts say the dish is nutritious and cheap.

It is not my intention to ridicule free discussion, but rather to call attention to its value in bringing to light all the bad as well as the good features of an invention, or the merits and demerits of a process, or the strong and weak points of a line of practice.

There is another great influence exercised by a society of this character, which, unfortunately, we cannot accurately determine. Experience shows, however, that it must exist. During the interchange of ideas, the brain is stimulated to unusual activity along the lines made prominent by the subject under discussion. New thoughts are developed and improvements are suggested. For the moment a participant becomes a worker in possibly a virgin field. He groups the facts gleaned from his experience, and, as a result, another improvement comes to light. The suggestion may be thrown out as a free gift, or it may be withheld for the time being, and eventually brought out in independent form.

Frequently men of high professional standing who cannot be induced to write a paper, or an article, will gladly participate in a discussion which has awakened their interest, and the world's record is enriched by thoughts which might otherwise never have been revealed.

Notwithstanding the classification or specialization that has gradually developed in the general field of engineering, the training which each individual receives leads him to gradually absorb a great deal of information which is not in his own line. Thus an electrical engineer should be, and frequently is, well versed in mechanical engineering. The civil engineer and the mining engineer should be familiar with both mechanical and electrical engineering in order to determine the best application of power under existing conditions. Although all citizens should be interested in the construction of public works in the best possible manner, in order to give really intelligent opinions, they should be trained engineers. There is a good reason for this, as years of study and experience are required to enable a man to intelligently select from different materials that which is best suited for a contemplated improvement. Take the question of pavements, for instance. In some cases the residents along a street are called upon to decide what kind of a pavement they prefer. Various conditions must be met, and each person is expected to contribute his own views to the discussion. He may want Telford because it is the cheapest, or Belgian because it is most durable, or asphalt because it is noiseless, or brick because he has heard that it was better taking all things into consideration. It is the life-work of an engineer to study and compare all these conditions, and it is his constant aim to get the very best results at the least possible expense. Professional pride will not permit him to authorize improper materials, for his reputation is based upon the character of his work.

If the engineer were more freely consulted in even what are considered the minor details of all public work, better results would be obtained. An eminent New Jersey judge recently made the statement that, during thirty years' experience, while every contractor for public work had been required to file a bond of guaranty for the faithful execution of his agreement in accordance with specifications, there had been no instance of suit being brought for recovery of damages on account of defective construction. This does not prove that the work has always been faithfully done, but rather that lax inspection under existing political methods has failed to protect the interests of the public.

One of the most important qualifications of a society like this is the continuity of its work. Its individual members are mortal, but, so far as we can predict, there is no reason why the organization itself should not be perpetual.

Its success is based upon scientific facts. Its printed records now form, and will continue to form hereafter, a growing history of mechanical and scientific development. The compiling of history, interesting and important as it may be, does not appeal to the general public. It is the activity of the living present which attracts the attention of the multitude.

Phenomenal scientific discoveries, or epoch-making inventions, are exceedingly rare. Year after year a society must plod along, satisfied with thoroughly investigating each progressive step, and aiding in that gradual improvement which eventually brings about those grand results which are appreciated only when we halt for a moment, and review the progress of a decade or a century.

There is one exceedingly important duty voluntarily undertaken by societies which is of immense economic value. This is the introduction of standard practice in the particular field in which they are interested. Various individuals and manufacturing concerns, working along their own lines, gradually introduce products or methods, until with the growth of an industry there are certain differences established that finally become a well-recognized evil for which there is no apparent remedy. Finally, this state of affairs is seen to obstruct the attainment of the best results, or is even wasteful, by requiring the unnecessary expenditure of time, capital and labor. It is brought to the attention of a technical society through proper channels, and committees of experts are appointed, who industriously undertake to remedy or mitigate the evil. So thoroughly entrenched are existing practices, that the work of reform is beset with difficulties. In spite of these adverse conditions the project is carried through, and in some cases has received governmental sanction. Various organizations have taken up questions of this kind, and, while it is hardly possible to determine the exact benefits thus attained, there can be no doubt that great good has been accomplished. Among the examples that may be cited are "Standard Screw Threads," by the Franklin Institute; "Standard Boiler Tests," by the American Society of Mechanical Engineers; "Standard Steel Rail Sections," by the American Society of Civil Engineers, and, within the present year, the "Standardization of Electric Generators, Motors and Transformers," by the American Institute of Electrical Engineers.

It is gratifying to know that men of affairs, whose time is valuable, will so heartily devote themselves to the solution of the perplexing problems arising in the course of establishing standards of such a character that they will meet with the approbation of those who are expected to conform with them.

It should also be remembered that to the Franklin Institute should be given the credit for the organization under government auspices of the National Conference of Electricians in connection with the Electrical Exhibition at Philadelphia in 1884. The organization of the International Electrical Congress of 1893 was undertaken by the American Institute of Electrical Engineers, and the publication of its proceedings was carried out by the latter when otherwise its records would have been hidden from the world. This congress established standards of nomenclature and of dynamic values and units which have been generally approved and recognized. There can be no doubt as to the public benefit arising from the existence of these organizations, but the carrying on of such work involves considerable expense, and this falls upon the members, many of whom feel that they receive no equivalent. This may be true within the limits of their past experience, but no one can tell what the future may bring forth. An item from a single contribution to the transactions frequently is of more value to an engineer than the cost of many years of dues.

The first thing a young man should do in entering upon his professional career is to become a member of a society where he will come in personal contact with his fellow-workers. He should take a sufficiently active interest to show that he is not only capable, but ready to do his part in advancing the general welfare. He will soon find that it is not only a satisfaction to be identified with the organized membership, but that it will also be a direct advantage to him in many ways. Although the membership of a national society must necessarily be composed of those who are rivals in business or in the employ of competing companies, all antagonisms due to these conditions are laid aside in striving for the general progress of the profession. Institutions of this character enjoy a high standing in the community, and such work as appeals to public recognition is fully appreciated. There is still lacking, however, that continued interest in their routine work which its importance demands. While universities and colleges are handsomely endowed and suitable buildings erected for their use as memorial gifts, societies must levy on their supporting members to build or purchase houses, and obtain their libraries in a similar manner, which are, nevertheless, frequently thrown open for public use.

Experience has shown that one of the most serious problems confronting a society of this character is the privilege of a proper meeting place, or, in other words, a suitable home. That the importance of such a building is fully recognized is shown by the efforts that are made to purchase one as soon as the revenue of a society becomes sufficient to warrant the expense. This is not an insurmountable difficulty in the case of national societies. The establishing of a home and library in the city which is selected for headquarters does not, however, meet the requirements of the entire country. In every city there is a sufficient number of men interested in scientific and engineering questions to form local societies or clubs which would be of great public value in the administration, for instance, of municipal affairs. It is in such towns that the lack of a suitable meeting place or the expense of maintaining one interferes with the formation of technical organizations. Their existence is not considered a public necessity, yet, when important municipal improvements are projected, there could be no more satisfactory discussion of the problems to be considered than would be elicited from a body of this kind. It would differ from a town meeting in several important respects. Each member would be trained to view the questions from a scientific standpoint. He would not be influenced by the political aspects of the case. He would base his opinions on the experience of others, and he would be familiar with the record of that experience or he would know at once where he could refer to it.

Having been assigned the duty of pointing out the advantages occurring from the existence of such organizations as the Franklin Institute, whose seventy-fifth anniversary we have gathered to celebrate, I have gone a little further and intimated that they might be still more useful if the people generally were closer in touch with their proceedings. They are really supplemental to our educational system. The fact is generally recognized that no matter how high may be the standing of a college graduate, his education in the school of experience ends only with his life. It is through these societies that the results of personal professional efforts are gathered and recorded. His thoughts are brightened, his best work is studied and appreciated by his colleagues. He is stimulated by healthy rivalry to do his best, and to honor the achievements of others.

We need have no apprehension as to the future of our great technical societies. There are the best of reasons for their continued existence and their healthy growth. Their foundations are deeply embedded and beyond the reach of those discordant elements which frequently revolutionize governments, divide our churches and overthrow the greatest financial undertakings.

Anniversary Meeting of the Mining and Metallurgical Section.

INTRODUCTORY ADDRESS.

By Mr. James Christie,
President of the Section.

Members of the Mining and Metallurgical Section, Ladies and Gentlemen:

The Mining and Metallurgical Section of the Franklin Institute celebrates this evening the completion of seventy-five years of existence of the parent society. The work of this Section forms an important part of the work of the Institute, inasmuch as mining processes and the extraction and preparation of metals obviously demand the highest culture of science and mechanical skill. These arts, which are now amongst the most important of our national industries, were of little importance seventy-five years ago, when our Institute was founded. At that time the United States was pre-eminently the home of an agricultural community. Within these years of the Institute's existence the development of the nation's mineral resources has proceeded at a constantly accelerating rate, and now the arts of mining and metallurgy have attained an enormous magnitude, and it requires no prophetic vision to foresee a gigantic growth in the near future. Iron, as the most abundant and the most useful of metals, naturally claims our first attention; and we are honored to-night by the presence of a man whose age and experience place him at

JAMES CHRISTIE.

the head of practical metallurgists. Mr. John Fritz, in age, antedates the Franklin Institute some two years. He had begun the active work of his life before the boiling furnace was introduced into the rolling-mill, before a rail had been rolled in this country, before anthracite coal was used in blast furnaces; and he saw the time when the total production of pig iron in the United States did not exceed that of a single modern blast furnace. It affords me special pleasure to introduce to you Mr. John Fritz, of Bethlehem, Pa., who will address you on the " Development of Iron Manufacture in the United States."

THE DEVELOPMENT OF IRON MANUFACTURE IN THE UNITED STATES IN THE PAST SEVENTY-FIVE YEARS.*

By JOHN FRITZ, Bethlehem, Pa.

I have been requested by your President, Mr. Birkinbine, and also by Mr. Christie, Chairman of the Mining and Metallurgical Section of the Institute, to give some reminiscences concerning the progress that has been made in iron and steel metallurgy in my lifetime and during the lifetime of the Franklin Institute.

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*[INTRODUCTORY.—It was my intention to have given a brief account of the early experiments with the Bessemer process at Cambria and Wyandotte, and also a brief notice of the earlier works that went into the business; I soon found, however, that it was not possible to do so in a paper such as I was called on to read, and, besides, Mr. Wm. F. Durfee and Mr. R. W. Hunt, who each by turns had charge of the experiments at Wyandotte, have already put the general results on record. Consequently, I will confine myself to such a paper as I was asked to give—some personal reminiscences of my connection with the manufacture of iron and steel, which is unfortunate for me, as I would much prefer to tell what others have done than what I have done myself. But, as I was asked to do this by the officers of your society, and did not seek the honor, I beg you will, as far as possible, excuse much that will doubtless seem egotistical, and ask you to bear in mind that what I have to say is only a general history of the early developments of the iron and steel industry in this country, with which others also had much to do.—J. F.]

This being the last year but two of the century that has done so much to change the face of society, and for the betterment of mankind, it will be interesting to take a brief retrospective view of the events that have taken place during this remarkable period, and in doing so we witness the most wonderful progress that has been made in the advancement of the arts of science and civilization, all the effects of which are far-reaching.

In the very front we see the phenomenal progress that has been wrought in all the various branches of manufacture in all parts of the civilized world. We look again and find that the manufacture of iron is in the lead, and that the United States comes in for a large share of this all-important branch of manufacturing industry, which is the advance guard of civilization, one which has done so much to build up this country and served her so well both in peace and in war.

JOHN FRITZ.

While I have not been asked to say anything about matters beyond the date of my own experience or the life of the Institute, it seems necessary, however, that a brief allusion should be made to the first puddling furnace and plate mill that were erected, in order that the great advance that has been made in this branch of the manufacture may be more fully appreciated.

The first puddling furnace in this country was built at Plumsock, on Redstone Creek, about midway between Connellsville and Brownsville, in Fayette County, Pa., in 1817. A flood caused the partial destruction of this mill. The machinery was subsequently removed to Brownsville. In 1819 a rolling mill was built at Pittsburgh in which there were four puddling furnaces. This mill was accidentally blown up, and permanently dismantled in 1829, and the machinery was taken to Covington, Ky. Both enterprises thus seem to have ended in disastrous failures.

About 1810 Isaac Pennock built a rolling mill (at that

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time called a "slitting mill") near Coatesville, in Chester County, Pa. In 1816 it came into the hands of Dr. Charles Lukens, a son-in-law of Isaac Pennock, and was operated by him until his death in 1825. It was during this period and on this mill that the first boiler plate was rolled in this country. The blooms were heated on a grate fire and the rolls were driven by an old-time undershot water-wheel. When a boy I heard the older men say that the mill was often short of power, and frequently all the workmen would run and get on the buckets and tread with them, in order to prevent a stall which would have caused fire cracks in the rolls, and, sooner or later, a broken roll. This being before the days of railroads, coal was hauled from Columbia, thirty-five miles distant, and the plates were teamed to Philadelphia, thirty-five miles away, and were shipped without being sheared. A notable circumstance about these works is the fact that they have always remained in the family of Isaac Pennock, and are now operated by his descendants of the fourth generation.

What I have now said will be sufficient to give you some idea of the condition of the trade at that time, and will enable you better to appreciate the great improvements that afterwards were made; and also brings us practically down to the birth of the Institute in 1824.

From 1824 until 1836 but little progress was made in the way of marked improvements. During the thirties there were some puddling furnaces built, to puddle run-out or refined pig metal, and eventually they got in the way of using some close-grain pig iron in connection with the refined metal.

In the early forties puddling began to come into general use, but only close iron was used. In the years 1844–45 the manufacture of rails commenced. This at once gave it the leading position in the manufacture of iron, which it held until it was beaten by the Bessemer process, to which I shall refer again.

About this time the manufacturers' trouble begins. The demand for puddlers soon exceeded the supply, and they thought they ought to have things their own way. Up to this time the old-fashioned Welsh hammer was the only mode in use for putting the puddled ball in shape for the rolls. The hammerman or "shingler," as he was called at that time, was the king bee, and when he went wrong, as he frequently did, the puddlers had to quit work until such a time as Mr. "Shingler" was ready to go to work, which sometimes required several days; and when at work woe be unto the puddler who might happen to be on bad terms with him.

The hammer striking a uniform blow, no coaxing could be done; consequently great skill was required during the first few strokes of the hammer to keep the ball in such shape that it could be edged and upended in order to get a good-shaped and compact bloom. Should the "shingler" fail in this, which he could and at times did, and that without any apparent intention, then a row was started which sometimes ended in a fisticuff, as we had bullies in those days as well as now, but not so well trained, and the rules of the ring were not such as they are to-day; if they had been, they would not have been strictly adhered to.

The next improvement in this line was the introduction of what was known as the "crocodile" squeezer, which was entirely unlike the hammer in every way, and it was so easily worked that almost any of the puddlers could put their own work in shape; but, unfortunately for the manufacturer, they could coax a ball into shape that was not properly worked in the furnace. So, while this was entirely satisfactory to the puddler, it was very unsatisfactory and unprofitable to the manufacturer, with the result that there was constant bickering between the employers and employés; a condition of affairs that should not exist.

Next came the "Burden" and "Winslow" squeezers; the latter was used for a time, but finally the "Burden" came into general use, and is to this day as nearly perfect a machine for the purpose intended as has ever been devised. Not alone on account of its simplicity in construction and the perfect manner in which it does its work, but because, also, it establishes justice between the ironmaster and the workmen from which there is no attempt to make an appeal. When a ball would break, the workman, without saying a word, gathered together the pieces and took them back to the furnace and worked them into a proper condition, and in the end the squeezer proved to be the puddler's friend. Notwithstanding all its good qualities, its introduction caused strife in practically all the mills that introduced it down to about the year 1856. Some of the strikes were long and bitter, and many incidents might be recited in relation to its introduction, some amusing, some ridiculous and others revengeful. However, soon after the system came in general use, an armistice was agreed upon, which finally resulted in a treaty of peace, which was advantageous to both parties.

In or about the year 1848, boiling came into general use, which was a great improvement, and puddling soon became the all-important branch of the great iron industry of the country, and continued in the lead until it was overtaken by the almost magical invention of Sir Henry Bessemer, to which I shall refer later.

Until 1840 all the pig iron produced in the United States was made with charcoal. My first connection with a furnace dates from 1839. It was driven by water, a wooden blowing-cylinder connected with the crank by a wooden beam. The crank, the journal and the wings that were fitted in the end of the water-wheel shaft to carry the wheel and to drive the blowing-cylinders. Neither of the journals were turned off, but were put to work just as they came out of the sand. It was blown by an open tuyere. The whole plant was of the crudest construction. The weekly make was about sixteen to twenty tons. It was placed against a bank, level with the tunnel-head, so as to avoid hoisting the material up. This was about the character of the furnaces in general use at that time.

I was sent there as a "cub" to put up a belly-pipe which was made at the shop in which I was learning my trade. When it was put in place it was, as I remember, about six or eight inches too short, and I supposed somebody had made a mistake in the length. The founder was a consequential-looking man, and quite stout, with a blue flannel shirt and his " pants " held up by a rather broad leather band buckled around his body, somewhat in the order of many we see to-day, but was not gotten up in the same style. He said rather brusquely that " it was all right." The pipe was connected at the rear end to the main pipe by a short leather connection, which I was told was to allow the belly-pipe to swing out of the way so that they could get the cinder out.

This was the general condition of the furnaces until 1840, when Mr. David Thomas, since affectionately called " Father Thomas," made the first anthracite iron in a commercial way that was made in this country. This was the commencement of the phenomenal development of the blast-furnace practice that has taken place in the latter part of this century.

We left the rolling mills in 1824 in a very crude condition, and there was no marked improvement in them until the manufacture of rails commenced, which, as already mentioned, was about 1844. But even at this time the plans of the mill and manner of building practically remained the same, being geared, and it seemed to me that the general impression amongst the rolling mill proprietors was that the more wheels they could get in the better was the mill. Down to this time the carpenter or millwright had largely the say, consequently wood was much used. The shafts were generally made square, and the fly-wheel and gear-wheels were secured on them by the use of wooden wedges, into which other thin wedges of iron were driven. No matter if the foundation was built of wood or stone, a large piece of timber was placed on top, to which the housings were secured; the idea being that it was essential that the train should have some elasticity in order to take the shock off the machinery, thereby preventing breakage.

After the manufacture of rails commenced in 1844 more rigid and better workmanship was required. The mills, as heretofore, were all geared, but the carpenter and millwright were superseded by the machinist. The shafts were now turned up, wheels were bored out, and the mill all fitted up in a more workmanlike manner.

From 1845 to 1856 there were but few improvements made, either in machinery or the manner of rolling, except the introduction of the rail-straightening machine which took the place of the sixty-pound sledge and a special man to handle it. When he wanted a rest the works had to come to a standstill until such a time as he was completely rested, sobered up, or restored to health, as the case might be.

The year 1857 is a memorable period in the history of the manufacture of iron. As before stated, in 1844 the forge carpenter and millwright were superseded by the machinist, who now comes to the front as a mechanical engineer, not full fledged, but with an amount of knowledge gained by experience which qualified him for the important duty which awaits him.

As I have already said, the year 1857 was a memorable period in the history of the manufacture of iron. Down to this time all the rails were rolled on a two-high train, the pile being passed back over the top roll, which meant a great waste of time and loss of heat. When the flanges once began to crack, which was one of the serious troubles, being all the time rolled in one direction, it greatly aggravated the difficulty. The result was that when an imperfection occurred in the flange, the trouble increased with each pass through the rolls, and so extended that it was a common occurrence for the flange to tear off the whole length of the rail and wind around the roll, forming what, in rolling mill parlance, was called a collar, which very generally ended in breaking some part of the train and often the roll.

The iron was frequently both red- and cold-short and all other shorts, and in addition to this would stand but little heat, consequently the end of the pile which entered the roll first would split and open out like the mouth of an alligator. Then, of course, it would not enter the rolls without force, which was applied with the buggy, using it as a battering ram. After making several vain attempts to get it to enter the rolls it very frequently had to be turned end for end. The loss of time taken up in going through all this was such that it was almost an impossibility to get a perfect rail. Had it not been for the use of putty, oxide of iron and the absence of inspectors there would have been but few rails shipped.

In order to get over the difficulty of the flanges tearing off we went to quite an expense. Some iron of a better quality was used for the flanges, which, in a measure, gave some relief in that direction. But the iron being much stronger, required more heat and greatly increased the difficulty of opening the end of the pile in the first few passes. We were now in a sad dilemma, and something had to be done. I was sick at heart, and had it been manly I would have run away.

But, during all this time, I was giving the subject much consideration, and had fully made up my mind that, if a three-high mill could be made to work, the difficulties could all be overcome; I, besides, had made up my mind that it was the only proper way to roll iron.

I was now prepared to suggest the building of a three-high mill, which I did; and the suggestion was met with a rebuff, which was not unexpected. They said in substance: " It was a visionary scheme; it had never been done, and had it been practical it would have been done long ago." In reply, I told them something must be done or there would be a large funeral, and I did not want to be one of the mourners. The subject was then more seriously taken up by the company, and it was suggested that a better ore should be secured as a mixture to improve the quality of the iron; but the location of the works was such that a suitable ore could not be got at a price that would permit it to be used as a rail mixture, so this course was abandoned.

The company now began to see that it was necessary that something should be done. The directors called a meeting and, after consultation with some practical iron men, decided to put up a geared two-high mill, and by greatly increasing the speed of the rolls, the rail would be finished in much less time, and consequently at a higher heat, which would prevent the serious trouble of rough and torn flanges. After some pertinent discussion, I was ordered to build a new mill, two-high, geared. As my patience had become exhausted, and being thoroughly disgusted and especially so with the geared mill, I most emphatically said I would not do it, as two of the most objectionable features of the present system would still be retained. I was then asked what right I had to dictate to the company in regard to the policy they should pursue in the line of their business. I answered that I had no right whatever, but that I was thoroughly convinced that it would not remove the difficulty and in the end would be a failure and the result financial disaster. Being a young man and the only capital I had in the world being my reputation, and that being quite limited, I did not purpose placing it in danger where the chances were so unequal. This interview ended in a suspension of hostilities, and for a short time nothing was said on either side. But the trouble in the mill still continued, and something must be done and quickly. Having already lost my reputation for complaisance and being considered as the most arbitrary of men they had ever met, I consequently concluded that I would do as I had been compelled to do before and many times since—assume authority and go ahead, which I did; and commenced work on the patterns. The drawings had already been practically completed.

After the pattern for the housing was well advanced, Mr. E. Y. Townsend, the Vice-President, came out to the works and I informed him of what I was doing, and again talked the situation over with him. He said nothing, but thought it proper to let the company know what was being done, to which I assented. In about a week, as I remember, he came to the works again. This time he was armed with a legal document opposing the spending of the money in the way it was being done. He handed me the document to read, which I did. I then handed it back to him and said nothing. He then asked me what I thought about it and the best course to pursue. In answer, I said: "You know the troubles we have had, and it is useless to go over them again, and you know my opinion, which is irrevocable." After some friendly talk on the condition and the importance of the change proposed, he said: "Go ahead and build the mill as you want it." I asked: "Do you say that officially?" to which he replied: "I will make it official." And he did so.

When I look back to that eventful interview, which took place on a Sunday morning long years ago, and recall to mind Mr. Townsend and myself, with evidences of failure on all sides, and surrounded by the gloom of future uncertainties, I cannot but feel it was the most critical period not only in my own career, but also in that of the Cambria Iron Company.

And here I wish to say that to Mr. E. Y. Townsend belongs the credit not only of the introduction of the three-high rolls, but also for a large share of the subsequent marvelous prosperity of the Cambria Iron Company, which followed the introduction of the three-high mill and its many accompanying improvements.

The opposition to the three-high mill now came in from all quarters. The heaters on the rail mill were unanimous in their condemnation, and waited on the company to tell them what a direful failure it would be. Next I had to meet the combined prejudice of the ironmasters, who were a power at that time. Some of them would tell the managers that the whole thing was certain to be a failure. Next came my friends, in the trade and out of it, begging me to abandon what would surely prove a failure and blast my reputation for life. One of my dearest friends, with whom I had been employed for a number of years, came to see me and, if possible, to get me to change my plans. To them all I said "No, I can make it work, and it is the only plan that can be adopted that will save the company."

After all these years there is no person other than myself who can fully appreciate the trying position the managers were in. On the one hand, I was to build a mill on an untried plan, and absolutely refusing to build the mill they asked for, knowing full well that only in a small degree would it remedy the trouble, and that the money spent on such a plant would be thrown away. On the other hand, there was a strong party of stockholders, protesting in the most positive manner against going on with my plans, and notifying the managers that they would hold them personally liable for all the loss and damage that might grow out of their unwise action, as they considered this action to be, in adopting a new and untried method that was against all practice in this and the old country, for at that time we were expected to be followers instead of leaders. Notwithstanding all the opposition and trouble we had to encounter, the work on the mill was being pushed along as fast as it was possible. But there were many difficulties in the way. The most serious was the want of proper tools and facilities for doing the work. Many makeshifts had to be improvised, which all required time and labor. During all this time there was much talk and speculation going on in regard to the final result, to all of which I gave but little attention.

At length the mill was completed, and on the third day of July, 1857, the old mill was shut down for the last time. On the fifth we commenced tearing the old mill out, as the new one had to be put in the same place. The work was pushed as fast as possible, day and night, but, as it was before the days of electric lights, the night work could not be done with the same expedition as to-day. At the same time everything in the rail department was remodelled and the floor line of the mill was raised two feet. On the twenty-ninth of the same month everything was completed and the mill ready to start. The starting of the mill was the crucial period.

In giving an account of the starting of the mill, I can probably do no better than quote from a paper written for a former occasion.

There were no invitations sent out. As the heaters to a man were opposed to the new kind of mill, we did not want them about at the start. We, however, secured one of the most reasonable of them to heat the piles for a trial. We had kept the furnace hot for several days as a blind. Everything being ready, we charged six piles. About 10 o'clock in the morning the first pile was drawn out of the furnace and went through the rolls without a hitch, making a perfect rail. You may imagine what my feelings were as I looked upon that first and perfect rail ever made on a three-high train.

And you may know in part how grateful I felt toward the few faithful men who were about me, and who had stood by me during all my trials and difficulties. Among these were Alexander Hamilton, the superintendent of the mill, and Thomas Lapsley, who had charge of the rail department, Wm. Canam and my brother George, all of whom have gone to their reward.

We now proceeded to roll the other five piles. When two more perfect rails had been rolled we were obliged to stop the engine for the reason that we were so intently watching the rolls that the engine had been neglected, and, being new, the eccentric strap got hot and bent the eccentric rod so much that the engine could no longer be worked. As it would have taken some time to straighten the rod and reset the valves, the remaining piles were hauled out from the furnace onto the mill floor. About this time the heaters, hearing and seeing the exhaust of the engine, came into the mill in a body from the opposite end of the mill to where the rails were. Seeing the unrolled piles lying on the floor, they took it for granted that the new train was a failure; and their remarks about it were far from being complimentary. Mr. Hamilton, coming up and hearing what they were saying about the mill, turned around, and using language more pointed than polite, told them if they would go to the other end of the mill they would see three handsomer rails than had ever been made in their country, Wales. After getting the engine in shape, the day being Friday, we ran all day, and at night put the regular night turn on.

Everything worked well up to noon on Saturday, it being our custom to stop rolling at that time. About six o'clock in the evening Mr. Hamilton and myself left the mill, and on our way home congratulated ourselves on the fact that our long line of troubles and disappointments was now over. About an hour later I heard the fire-alarm whistle blow, and rushing back to the mill, found it one mass of flames from end to end. In less than one hour's time the whole building was burned to the ground, and a story was started that the new mill was a failure, and that we had burned the mill to hide our blundering mistakes. The situation of affairs on that Saturday night was such as might appall the stoutest heart. The product of our labors and anxieties lay there, a mass of black and smoking ruins, and the money that was so hard to get with which to build the mill was gone. The prospect was indeed gloomy, but there was one gleam of light amid all the darkness; and that, the pile of perfect and new rails, which, as Mr. Hamilton had said, had never been beaten in Wales, from which country the greater part of the rails used at that time came. Above all, the mill had been tried and found to work magnificently, and it was these two facts that gave us all fresh courage, and enabled us to rebuild the mill.

The next day being Sunday, it was devoted to rest and to thinking over the matter. On Monday morning we commenced to clear up the wreck, all the workmen giving a full day towards it, and began the work of rebuilding. In four weeks from that time the mill was running, and made 30,000 tons of rails without a hitch or break of any kind, thus making the Cambria Iron Company a great financial success, and giving them a rail plant far in advance of any other plant in the world. This position they held, unquestioned, both for quality and quantity until the revolutionary invention of Sir Henry Bessemer came into general use.

In the construction of the three-high mill there were many changes and improvements on the old two-high mill. Up to this time the leading spindles had a groove cut in them to weaken them, so that if any extra strain should come on the rolls, they would break instead of the roll; and the couplings were made light so as to act as a kind of a safety-valve. Then there was a breaking box placed between the screw and the roll. If there was not one of these safety devices breaking each day, the pattern was made lighter. The result was that some of them were breaking several times daily, furnishing a constant source of annoyance. In building the new mill they were all made so strong that they were not calculated to break. The breaking box on top of the roll was made solid, as they were apt, when they gave way, to break the collars on the rolls, which should, if possible, be avoided. All these changes were stoutly opposed by the foremen and workmen of the mill. A few days before the mill was ready to start, the superintendent of the mill discovered that the breaking box was solid; he then got the pattern and took it to Mr. Lewis, the pattern-maker, and told him there was a mistake, that it was made solid. Mr. Lewis told him that it was made as the old man had ordered it, to which the superintendent said, " the old man has gone crazy." He looked me up and wanted to know if I had ordered the breaking box for the new train solid. I said, "yes;" he replied that if with solid spindles, heavy coupling boxes and solid breaking boxes on top of the rolls, a piece should enter a wrong groove, or a collar should form on the rolls, which was sure to take place, the mill would be broken to pieces; to which I replied: " I would rather have a grand old smash-up once in a while than be continually breaking something and keeping the mill standing half the time and the metal wasting in the furnace." He said: " Well, you will get it, sure;" but we did not, and, as before stated, the mill made 30,000 tons of rails without a break of any kind, which, at that time, on iron, was nearly a year's work.

The heating furnaces were rebuilt, making them larger, the roofs much higher, and the length of the furnace greatly increased, which about doubled the work that had previously been done. There were also a number of improvements made on the train to facilitate the work, and make it much easier for the men. Among them was the introduction of the driven feed-roller, out of which, later on, came the blooming table, which is now indispensable in the rolling of steel ingots either on a three-high or reversing mill.

In 1864 the Bessemer process was introduced in this country. Its introduction and perfection will ever remain one of the most interesting epochs in the history of the iron business.

As already stated, the forge carpenter and millwright were superseded by the machinist. Immediately after the introduction of the three-high mill all the rail mills in the country were changed, and all the new ones that were built adopted the same plan. In fact, as Mr. B. F. Jones, one of the oldest, one of the leading and one of the most practical and successful ironmasters in the country, and one of the very first to see the advantages of the system, said to me a short time since, it was the commencement of the great improvement which took place in the iron works after 1857 which paved the way for the introduction of the phenomenal "Bessemer" process, which, as the Hon. Abram S. Hewitt says, takes its rank with the great events which have changed the face of society since the time of the Middle Ages.

At this time the machinists before alluded to were called to the front to brave the danger and fight the great battles that have ever to be encountered in the introduction of new metallurgical processes, and in none were the difficulties more alarming and disheartening than in the Bessemer process. These men had now received a training which eminently fitted them for the duties they were called upon to perform. Having been inured to hard work, they entered into this new field with such an amount of energy and determination that it made failure impossible.

In witnessing the beautiful and interesting but simple process of blowing a heat of metal, and the regularity with which it is done at this time, and the quantity turned out, it is impossible for one wholly unacquainted with its early history to even in a measure realize the fear and anxiety of those who were responsible for the result. When a charge of metal was poured into the vessel our anxiety commenced, and as the heat increased, our anxiety increased in a corresponding ratio, until both became intense. It was when the heat was greatest that accidents were most likely to happen. The refractory material with which the converters were lined, especially the bottoms, would become plastic, and when in that condition the effect of the heat and the blast would waste the tuyeres and bottoms away so rapidly that from one to three heats were all we could get off of one bottom. Frequently they would give out at the first heat, then out would come the metal through the bottom; and having to use much water about the converter, the place under the vessel was at all times wet, and the result was explosions, often very dangerous, as the hot metal was blown in all directions, frequently inflicting serious injuries on the workmen, a calamity greatly dreaded and the cause of the gravest anxiety to those in charge. When an accident would occur anywhere about the works the first question asked would be: "Is any one hurt?" If not, we would go to work at once to repair with that object only in mind. If, on the contrary, some of the workmen were killed or seriously injured, it was impossible to describe the distress of mind that the person in charge had to endure. The anxiety one had when the charge was put in the vessel was increased with the heat until the heat was blown; but it did not end with the blowing of the heat. When the vessel was turned down it sometimes went too far and some of the metal ran out, resulting frequently in a grand pyrotechnic display of an exceedingly dangerous character. The next operation was to get the metal in the ladle, which was generally not a very difficult one, but it would frequently burn through the ladle, and then the only thing that could be done was to let it run into the pit and order all hands out of the way, for fear of an explosion. As soon as the metal was set all hands commenced to clean the pit, which was no easy task. Here were eight tons of molten steel in the pit burned fast to ingot moulds, bottom and sides of the pit, and to everything that would not burn up. If we were so fortunate as to get the ladle over the pit in good shape our anxiety was not yet at an end. It quite frequently happened that the stopper would pull off the end of the rod; then we had to use what we called a pricker to open the nozzle from the bottom. If the metal happened to be cold, which at that time it was apt to be, the nozzle would freeze up, as we called it; then the metal would have to be poured out of the top of the ladle into the mould, cinder and steel all together, with the result that generally the most of it got into the pit; then, again, if we escaped an explosion we still had a mess in the pit. Altogether the difficulties we encountered were enough to appall the bravest hearts. My brother George once said, when at Cambria, that he did not believe there was a man who ever went into the Bessemer business, and was responsible for the result, who did not at times wish he had never gone into it; and so far as my experience goes I can fully verify it. And, further, I think that, if it had not been for the interesting and exciting character of the business, but few men would have been willing to endure the trouble and anxiety and to endure the physical labor and danger to which he and the workmen were constantly exposed long enough to have placed the business on a commercial basis.

Having alluded to the trouble we had with the converter tuyeres which caused so much anxiety and loss of time, I will now explain how we got over the difficulty at once. We were only getting from two to four heats off of a bottom and then would have to turn the vessel down and put in tuyeres during the blow. It so happened that, at a time when we were having more than the usual trouble, the vessel was turned down and we were putting in two tuyeres when I was sent for, to go to the blast furnace, there being trouble there. As soon as the vessel was turned up I started for the furnace, not in the serenest state of mind; on the way over I was thinking over some new device for making the bottoms so that they could be burned in order to make them harder and better able to resist the action of the blast, as I had been thinking that that was one of the troubles. As I went into the furnace I noticed some firebricks about 5 inches square and 16 inches in length, such as are used in blast-furnace lining. At once I ordered some of them sent over to the converting department, and as soon as I could I went over and had one of them placed on end in the bottom between the tuyeres and well rammed in with ganister, put in the oven and well dried and put in the vessel. Result: Twelve heats off of one bottom.

From this time our troubles began to diminish, and instead of making ten and twelve heats per day we soon ran up to fifty and sixty heats in twelve hours, and some of the works are now making seventy and eighty. This system of making bottoms was at once generally adopted, and is still in use.

I shall now return to the rolling mill. As already stated, with the introduction of the three-high mill in 1857, the commencement of the great improvement in rolling mills and machinery connected with them took place. The rolls were made larger in diameter, better fitted up, and a more powerful and a much better class of engines was introduced, larger and better heating furnaces were built, and many labor-saving devices were introduced. But with the marvellously increased production of Bessemer steel it was evident that a larger ingot must be used in order to prevent congestion in the pit furnaces and rolls. This, of course, involved the building of larger, heavier and more rapid working machinery.

In 1868 the lamented Holley, who later on became the consulting engineer of the Bessemer works and so remained until his death, and to whom the country is largely indebted for the introduction of the Bessemer process and for many improvements and important suggestions in the art, built a three-high blooming mill at Troy, N. Y. This mill had the top and bottom rolls stationary, the middle roll being moved up and down, to suit the work, by four screws passing through the bearing carrying the rolls. In the bearing there was a thread corresponding to the thread on the screws, which screws were driven by power. He also had lifting tables, front and back, fitted with loose rolls, and the ingots were pushed into the rolls by hand both in front and in back.

In 1871 my brother George, then superintendent of the Cambria Works, built a three-high blooming mill in which the middle roll was stationary and the top and bottom ones movable, with feed tables both front and back, and the rollers driven by power taken from the train. He also introduced what is called a " pusher " to adjust the ingot in a proper position on the table and also an arrangement for moving the ingot on the table in proper position to enter the rolls.

In 1872 we built at Bethlehem, Pa., a three-high mill in which all the rolls were fixed, with tables similar to those at Cambria, but driven by an independent power which very much simplified the arrangement of driving the tables. This is the plan of mill that was generally adopted, and for a moderate sized ingot and quick working is probably the best plan of mill. But for heavy ingots and for variety of work the reversing mills are preferable.

The .rail trains are, with two exceptions, three-high, with larger rolls, very heavy housings and fittings, and more powerful engines, and generally have some kind of labor-saving device attached to the rolls. In fact all the modern rail mills have introduced labor-saving machinery to such an extent that there is, comparatively speaking, but little left for man to do. This is to a great extent due to the introduction of steel, as it rarely either splits or cracks in rolling, while iron is ever liable to do both, which renders the use of delicate automatic machinery more difficult in rolling iron than in rolling steel.

Many instructive, interesting, annoying and amusing incidents which might be related occurred in connection with the almost magical developments which took place in the manufacture of iron and steel during my long association with the business. But time will not permit.

We left the blast furnaces in 1840, which, as before mentioned, was the commencement of the use of mineral coal, from which period the greatly increased production commenced. While there was no practical change in the principle of making pig iron, yet, the continued increase in size of the furnace, the increased pressure and quantity of blast, the introduction of the Whitwell system of fire-brick stoves, the better understanding of furnace working, the increased knowledge of the chemistry of pig-iron making—all these, coupled with the indefatigable determination of the men in charge, have contributed to bring about the unprecedented and phenomenal production which has so amazed the iron makers of the world.

In 1868 the manufacture of acid open-hearth steel commenced; but its progress was slow, and following the Besse mer, this process not being so interesting and exciting, did not command the attention and respect to which it was entitled. The fact that the Bessemer was in the lead and the machinery was already in use, and that the knowledge of refractory material and in the handling of the steel was acquired, made the introduction of the open-hearth process easy compared to the Bessemer. But the fact that it quietly made its way into general use does not in any way detract from its great usefulness, and, with the invention and introduction of the "Thomas" basic process and its application to the Siemens-Martin open-hearth system, it takes rank only second to Bessemer as one of the greatest metallurgical inventions of the age. And taking into consideration the character of our ores and coal, and their geographical location, the superiority of the metal produced by this process, for structural and machine purposes, may cause it in the near future to outrank the Bessemer in value and general usefulness.

When we look back to the commencement of the last half of the present century, and take a thoughtful survey of all the inventions and improvements that have taken place in the arts of metallurgy during this period, the complete reversal of the position that iron and steel formerly held in relation to each other, the superiority of steel over iron in the useful arts, and the immensely increased production which is unparalleled in the history of metallurgy, it seems impossible to fully realize that so great a change could have taken place within so brief a time.

While we have properly received great credit for the unprecedented developments we have made in the iron and steel industry in the United States, we must not forget that it was the inventions of Cort, of Mushet, of Bessemer, of Siemens, and of Thomas that enabled us to accomplish such important results; and to them all civilized nations owe a debt of gratitude for the incomparable blessing their inventions have conferred on society.

Yet how few of us even for a moment think of the trials, troubles, disappointments, mental anxiety and bodily toil these men had to undergo in the perfection and introduction of their inventions, besides suffering the sneers and jibes of those who imagine that an inventor is nothing but a wild enthusiast, and treat him accordingly. The story of many inventors is truly pathetic and none more so than that of the lamented Thomas. The personal side of the story of the inventor of the basic process can only be appreciated by the reading of his life.

It should not be forgotten that England is the birthplace and home of the "Iron and Steel Institute," and much of our success is due to the information we have gained from the invaluable papers read at their meetings and the discussions that followed them. Here I wish to say that I would commit an act of ingratitude should I fail to give credit to the brave and noble workmen who, throughout my long connection with the business, have ever stood ready to meet any emergency, no matter what the danger or difficulty might be. All that needed to be said was, "Come, boys," but never " Go, boys," and if the difficulties were not insurmountable they were sure to be overcome; and too much credit cannot be given to these fearless and energetic men for the almost fabulous progress that has been made in the manufacture of iron and steel in this country.

Having already intimated that the United States was not the original home of the iron and steel industry, I will again refer to it.

When I look back to my early days in the iron business long, long ago, probably too long, it brings to mind one of the happiest periods of my life. After my daily labor was done I was free from all care until the next morning. After supper, at half-past six, then a simple meal, I returned to the works and helped the puddler, heater or roller, as the case might be, until about 10 o'clock. At that time the practical men, puddlers, heaters and rollers, were generally Englishmen and Welshmen. After the heats were charged in the furnaces, and while waiting for the charges to become heated, they would get their pipe—" cutty " they called it—and sit down on a pile of pig or puddled iron, as happened to be most convenient, and take their smoke. Having gained their confidence, I would take a seat by them and then they would tell me about the works in England and describe how their mills were arranged, their system of rolling, the principle and construction of their puddling and heating furnaces, and how to work them. As I spent my nights in assisting them to puddle, heat and roll, I gained a very general practical knowledge of the manufacture of wrought iron, which soon became of great value to me; and to the nights spent in the works with these hearty and generous workmen I owe much of whatever success I may have attained in after life. For the kind and generous manner in which I was always treated by them they ever have a green spot in my memory. In comparing this happy period of my life with what I have since many times gone through, it might, with propriety, be compared with the "Elysian Fields."

How little do the younger men that now have charge of our great iron and steel industries know or even think of the severe mental strain, the great amount of bodily toil, the vexation, the surprises, and the disappointments that had to be endured by the men in charge during the erection and perfection of these vast establishments that are now engaged in the manufacture of iron and steel. And, gentlemen, let me here say that this great work was not accomplished by command but by example. It was the men in training, before alluded to, who erected, perfected and put in operation these most marvellous enterprises of the age. And to these noble, brave and energetic men the people of this country owe a debt of gratitude for the far-reaching results they so thoroughly accomplished, and which have already changed the social condition of our vast territory. They have furnished us with a material which for quality and cheapness and the quantity furnished in a given time is without parallel, and could not have been realized by any other known methods. Without it the building of trans-continental roads would have been almost impossible. Had the rails been made in the old way out of the puddled iron, with the increased traffic on the Atlantic ends of the lines, they would be worn out before the Pacific coast could have been reached. The credit does not end here. The reduction of freight rates, owing to the general use of steel rails, is so enormous that it has been intimated by one of our most distinguished public men that the saving alone on the cost of transportation due to the use of steel in the place of iron would, if available, amount to a sum sufficient to pay our national debt in a comparatively short time.

In addition to the use of steel for rails, the Great West is being fenced with steel at a cost that seems almost fabulously cheap, and this product is being used largely for many other purposes. It was formerly iron that was used for structural work, now it is steel; and it has practically superseded the use of wrought iron. Steel is largely used in the construction of all grades of machinery employed in the manufacturing arts. It is the base of our immense inland system of transportation. It is this imperial metal that has enabled the engineer to perform the daring and remarkable engineering feats which he has accomplished during the last half of the century, without which they would have been practically impossible. It is the material used in the construction of these monster floating palaces that cross the vast ocean with the regularity of a railroad train.

Fifty years ago steel was a luxury to the engineer. Modern practice of steel-making in the hands of the mechanical engineer, the metallurgist and the chemist has wrought wonders in producing a material which is used alike in the manufacture of articles of the most weighty, the rudest and cheapest grades, and in the construction of the most intricate, the finest and most delicate implements and machinery. And it is boldly asserting its value and importance through every walk of life.

It is to the invention, introduction and perfection of the modern system of steel-making in this country that we are indebted for the education of our people in the scientific, mechanical and metallurgical arts, which has enabled them to erect such manufacturing plants as were necessary to supply our Government with the sinews of war, which made it possible to achieve those glorious victories which at once placed us in the front rank among the nations of the earth.

Production of Pig Iron.—The total production of pig iron in the United States in the past eighty-six years is shown in the following table:

TOTAL PRODUCTION OF PIG IRON IN THE UNITED STATES FROM 1810 to 1898.*

YEAR.	Long Tons.	YEAR.	Long Tons.
1810	53,908	1874	2,401,262
1820	20,000	1875	2,023,733
1830	165,000	1876	1,868,961
1840	286,903	1877	2,066,594
1850	563,755	1878	2,301,215
1854	657,337	1879	2,741,853
1855	700,159	1880	3,835,191
1856	788,515	1881	4,144,254
1857	712,640	1882	4,623,323
1858	629,548	1883	4,595,510
1859	750,560	1884	4,097,868
1860	821,223	1885	4,044,526
1861	653,164	1886	5,683,329
1862	703,270	1887	6,417,148
1863	846,075	1888	6,489,738
1864	1,014,282	1889	7,603,642
1865	831,770	1890	9,202,703
1866	1,205,663	1891	8,279,870
1867	1,305,023	1892	9,157,000
1868	1,431,250	1893	7,124,502
1869	1,711,287	1894	6,657,388
1870	1,665,179	1895	9,446,308
1871	1,706,793	1896	8,623,127
1872	2,548,713	1897	9,652,680
1873	2,560,963	1898	11,773,934

* Compiled by the American Iron and Steel Association.

PRODUCTION OF PIG IRON, STEEL INGOTS AND CASTINGS, AND FINISHED IRON AND STEEL IN THE UNITED STATES FROM 1890 TO 1898 INCLUSIVE.

YEARS.	Pig Iron. Gross Tons.	Bessemer Steel Ingots and Castings. Gross Tons.	Open Hearth Steel Ingots and Castings. Gross Tons.	Total Steel. Ingots and Castings, Including Crucible. Gross Tons.	Finished Rolled Iron and Steel. All Kinds. Gross Tons.
1890	9,202,703	3,688,871	513,232	4,277,071	6,022,875
1891	8,279,870	3,247,417	579,753	3,904,240	5,390,963
1892	9,157,000	4,168,435	669,889	4,927,581	6,165,814
1893	7,124,502	3,215,686	737,890	4,019,995	4,975,685
1894	6,657,388	3,571,313	784,936	4,412,032	4,642,211
1895	9,446,308	4,909,128	1,137,182	6,114,834	6,189,574
1896	8,623,127	3,919,906	1,298,700	5,281,689	5,515,841
1897	9,652,680	5,475,315	1,608,671	7,156,957	7,001,728
1898	11,773,934	6,609,017	2,230,292	8,932,857	8,513,370

I conclude these reminiscences with the accompanying statistics compiled by the American Iron and Steel Association, which show the wonderful progress that our iron and steel industries have made since 1840, when I started out to learn my trade as a blacksmith and machinist.

PRODUCTION OF ALL KINDS OF CRUDE STEEL IN THE UNITED STATES.

	Bessemer Ingots. Gross Tons.	Open Hearth Ingots. Gross Tons.	All Other Steel. Gross Tons.	Total Gross Tons.
1867	2,679	0	16,964	19,643
1895	4,909,128	1,137,182	68,524	6,114,834

PRODUCTION OF PIG IRON IN THE UNITED STATES.

	Gross Tons.
1840	286,903
1890	9,202,703
Estimated production for 1899	13,500,000

THREE-QUARTERS OF A CENTURY'S PROGRESS IN MINING AND METALLURGY.

By Chas. Kirchhoff,
Editor *The Iron Age*, New York.

CHARLES KIRCHHOFF.

It is with swelling pride that we may pause to look over the achievements in mining and metallurgy during the past seventy-five years. Within that brief span, which, as we reckon generations, has extended over only two and a half, there have been created our great industries of to-day. Our country may look back over what has been accomplished with satisfaction, even if we admit frankly and fully that we have been blessed with extraordinary resources. It may seem almost crude to gloat over mere arrays of figures, and the reproach, occasionally made, that we worship quantity unduly, has some justification, yet the record is an amazing one, nevertheless. A more serious criticism is that we have been prodigal of our heritage. Let it be admitted that we have been, and are even still, in some respects, wasteful and extravagant. Much of that reproach vanishes, however, when the conditions are taken into account. In the arts, in engineering and in manufacturing, after all, it is the balance-sheet which rules, and, from an economic point of view, waste may be not alone justified, but be actually imperative.

It is difficult to measure progress, qualitatively, in branches like mining and metallurgy. It is expressed in the more complete utilization of the natural resources, as in the increase in the total extraction of the contents of a coal bed. It is in evidence in the form of a capacity to utilize bodies of ores, lower and lower in grade. It is proven by ability to produce from rebellious, or impure ores, metals nearly chemically pure, and commercially available for a wider and wider range of consumption. It finds expression in the disappearance of the supremacy of the brand, only too often the creature of fortuitous circumstances. It is measured by an expansion of markets which may be due to the fact that technical progress has proceeded more rapidly in one country than in others.

For these reasons a simple enumeration of statistics of production only partially reflects the development of an industry. Yet that in itself shows a record of which we may well be proud.

Practically seventy-five years ago our greatest mining and metallurgical industries were in their infancy, and many were not even started. We had only begun to mine small quantities of anthracite coal. We were producing iron, but had at an earlier date been relatively more important as an iron-manufacturing nation. Silver, copper and lead were made in irregular, very small quantities. Zinc was not produced, and the gold output, with the Georgia gold rush of 1828–1830, was about to begin. In other words, our mining and metallurgical industries were of so limited a character that, compared with the ancient operations of the leading European nations, they were insignificant to a degree.

While it is true that our miners and smelters rose to the occasion when they were called upon to meet special conditions, the general fact is apparent, from a study of our development, that we first copied and then adapted the methods approved by experience in Europe. We were forced and did create hydraulic mining to collect the gold from alluvial deposits. We developed the preparation of anthracite for the market. We had nothing to guide us in handling the copper rock of Lake Superior. The Washoe process was worked out to treat the silver ores of the Comstock lode. There were few precedents for methods in the petroleum industry, and had to learn by ourselves how to collect, distribute and utilize natural gas. But Cornish, Welsh and English miners long controlled the working out of our mining methods. German and English metallurgists guided our first steps in beneficiating our more complex silver, lead and copper ores.

One of the most brilliant reports on the state of the art ever written, that of Abram S. Hewitt on the Paris Exposition of 1867, is a confession of superiority of European methods in iron manufacture, which is almost staggering to one who reads it in the light of the present day. I cannot help feeling that the recognition of our indebtedness to European practice in the earlier days should be insisted upon, since it is becoming altogether too common to assume that we are the chosen people so far as the mechanic arts are concerned. Many of you have, undoubtedly, like myself, encountered that feeling in such places that the fear of the danger of overconfidence is naturally aroused.

A striking fact is the growing interdependence of the various branches of the mechanic arts as contrasted with the conditions prevailing seventy-five years ago. The one relies upon the other, not alone for its products, but is aided too by suggestions and support. The metallurgist's progress is accelerated by the mechanical engineer, and the latter looks to the former for increasingly strong and reliable materials. The electrician has greatly widened the capacity for improving methods on the part of the copper producer, and in turn is under a debt to him. The cheapening of fuel, due to the efforts of the coal miner, and the achievements of the rail-maker, are returned in kind by the railroad builder, who has taught both much of value in transporting materials. Thus, all are shoulder to shoulder in the march of progress, mutually helpful and united—all-powerful.

To a constantly-increasing degree pure science, primarily in search of the truth for its own sake, sheds its searchlight along the path, and has become a closer and more valued ally year by year. Many of us will recall how the majority of active workers looked askance at this meddler, preferring to allow their own fancy full sway whenever they stopped to seek for causes or explanations. We may sometimes become impatient when the laborious and apparently hypercritical methods of the scientist do not more promptly clear an obscure point, or furnish us with a suggestion for successful new lines of work, but the day has long passed when we treated research with grudging respect, if not with open hostility. No one is now readier to acknowledge his indebtedness to the chemist or the physicist than the manager or the practicing engineer. The fear is disappearing of impracticable science on the one hand, and of unscientific practice on the other. And foremost in the work of harmonizing both in this country has been the time-honored body whom you, Mr. President, represent. The splendid array of the volumes of the *Journal* of this Institute is, in itself, the greatest monument to the man whose name it bears, and to those who have labored in pursuing in his spirit the promotion of science and the arts as a means toward promoting the happiness of mankind.

MINING.

With the widespread search all over the world, and the increasing number of trained observers, there has been an enormous accumulation of observations and data relative to mineral deposits. In the case of bedded deposits, the relations between mining development and economic geology have become closer and closer. But, on the whole, it cannot be said that this branch of science has given much direct aid to the metal miner. The systems of extraction have not undergone any radical improvement. On the whole, they are modified more frequently to meet more closely local conditions. It is rather in the work of excavation proper that progress has been most striking. It was J. J. Couch, a Philadelphian, who, in 1849, patented the first percussion drill ever made. Herman Haupt experimented with rock drills at the Hoosac Tunnel, from 1856 to 1861, while the first drill tried in mining was that of Schumann, at Freiberg, in 1857.

Colladon had proposed to use compressed air to work drills as early as 1852, but general attention to rock drills driven by compressed air was attracted by their employment at the Mont Cenis Tunnel in 1861, the plan to adopt them having been approved in 1857, as the result of Sommeiller's work. Quickly following upon the start thus made by power drills, came the introduction of high explosives. Nobel first applied nitroglycerine in 1863, and its use was begun in 1866 at the Hoosac Tunnel. A year later Nobel introduced dynamite, and since then power drills and high explosives have wrought a complete revolution in mining, by increasing the speed of development and extraction, by very greatly increasing the efficiency per man employed underground, and by heavily reducing the cost. By constant improvement in design and detail of both compressor and drill, machines have been created which have a wonderful life and efficiency, considering the adverse conditions under which they are expected to operate. What the defects in design in the early days meant is illustrated by the fact that in 1864, in the Mont Cenis Tunnel, it took an equipment of seventy Sommeiller drills to keep eight steadily at work, and in 1867, 200 were needed to maintain sixteen in actual operation.

The mechanical engineer and machine builder have given their powerful aid, too, in improving pumping and hoisting machinery. The simple and effective American direct-acting pump has done valuable service to mining, although for heavy service and large quantities of water it is giving way to more elaborate engines. In hoisting appliances, for deep mining we long remained behind European practice, our shallow mining not calling for heavy engines. During the last decades, however, some splendid equipment in magnitude, in speed and in economy of operation has been designed in this country, some of the greatest of these engines having been built in this city.

Underground traction has undergone far-reaching changes. Wire-rope haulage was introduced into collieries long before San Francisco led in surface cable traction, and in this country pneumatic and electric haulage were very promptly adopted and very rapidly developed. These, however, are only recent achievements, progress in underground haulage having been very slow for decades.

In timbering the Comstock square set was a characteristically American creation to meet exceptional conditions, and it is true that the preparation of mine timbers above ground by machinery was first practiced in this country.

For a long time the concentration of ores was neglected, simply because in many remote sections in the United States it did not pay to turn to mechanical dressing and because the oxidized surface ores, easily smelted, did not offer opportunities. An exception must be made of the Lake Superior copper region. There the Ball steam stamp quickly superseded the time-honored battery. Subsequently, Leavitt reduced the steam consumption by compounding, and more recent practice has proven that the spring foundation is not equal to the solid anvil in bringing out the highest efficiency. Ore concentration has been well developed in later years in Southeastern Missouri, and the low-grade lead and copper camps of Colorado, Utah, Idaho and Montana.

It would be a serious oversight, in dealing with the treatment of ores, to overlook the enormous influence which the introduction of the Blake crusher has wielded in the efficient handling of rock. Nor should later types of crushers, like the Gates, be overlooked.

An example of steady progress in crushing apparatus is furnished also by what is known as the California stamp mill. Every detail has been watched and worked out for decades, and a number of efficient self-feeding appliances have been added, until to-day there are enormous plants pounding away year in, year out, without any intermission, with merely a crew of inspection to represent the labor account.

It seems certain that the part which the rock drill has played in general mining is destined to be paralleled in coal mining by the modern coal-cutting machinery. The difficulties inherent in handling mechanical apparatus in low rooms may account for the fact that progress has apparently lingered so far behind in this field. In Europe, as well as in this country, inventors took hold of the problem in the fifties, but little headway was made for many years. It is only quite recently that machinery for this purpose is being introduced with a rush. Among the pioneers were Harrison with a pick machine, and Lechner with a cutter-bar machine. All the earlier types were driven with compressed air, and it was not until 1889 that electricity was applied to the Jeffrey cutter-bar machine, since superseded by the electrically-driven chain breast machine. How rapid has been the development of this branch of work in this country in recent years is shown by statistics compiled by E. W. Parker, of the United States Geological Survey. In 1891 6,211,732 tons of coal were mined by machines representing 6·66 per cent. of the whole. In 1898 the tonnage had jumped to 32,413,144 tons, or 20·4 per cent. of the whole. It is not too much to say that, from an economic point of view, this is the most far-reaching and significant recent development in mining.

A splendid achievement in mining was that of handling auriferous sands by hydraulicking. I do not remember ever having noted in our literature any definite data which might fix the credit for this upon any one man or group of men. The date is placed at about 1853, and in those stirring times, so soon following the discovery of gold in California, probably no record was left. The further stages of its development are coupled with the names of a number of inventors of nozzles and many ingenious hydrodynamic and hydrostatic contrivances, and in its greater days, before the anti-debris laws in 1882 cut off the work, bold and splendid engineering work was done in connection with these undertakings.

In more recent times some very thorough work has been done in one branch of ore dressing, and that is, in magnetic separation of iron ores. A number of American inventors, among them Ball & Norton, Wenstrom, Wetherill and Edison, have labored to utilize the lower grades of magnetites in the Eastern States. The problem of cheap and effective crushing involved has been carefully studied and brought out new ideas, but economic conditions for a while pushed the whole undertaking into the background. Recent events point to fresh opportunities in this direction.

METALLURGY.

Gold.—In the metallurgy of the precious metals marked progress has been made, although no really revolutionary methods have come to the front until the present decade brought the cyanide process. In gold extraction the improvement in the California stamp mill, largely mechanical, has already been alluded to. There have been added, in the amalgamation process, some ingenious contrivances, but it was not until the experienced chemist drove out the horde of so-called "professors" and charlatans that the treatment of auriferous concentrates and pyrites was a success. The chlorination process, together with the improvement in the design and operation of the batteries, and the introduction of the Frue vanner and machines of its type, has rendered possible the profitable treatment of very low grade ores. These are to-day prosperous enterprises based on a yield of $\frac{1}{10}$ of an ounce of the yellow metal to the ton of rock—a quantity so minute that no gold is visible in the ore, week in, week out.

The chemist again has intervened in recent years. While the solvent power of cyanides on gold was known early in this century, it was not until the later eighties that the McArthur-Forrest process made that method practicable by utilizing the fact that zinc shavings may be used as a precipitant.

For the treatment of more complex ores there was developed relatively early, at the Argo Works in Denver, a series of methods dependent upon the employment of copper as a carrier, and more recently pyritic smelting is gaining ground. It is based upon the treatment of sulphide ores in the blast furnaces, so that a considerable part of the heat produced by their oxidation is utilized in their fusion. Small quantities of lead or copper serve as collectors of precious metals.

Silver.—Although the patio process of amalgamation was invented in 1557 by Bartolome de Medina, at Pachuca, followed in 1590 by the cazo process of amalgamation invented by Alonzo Barba, at Potosi, no real improvement followed in the succeeding centuries. On the heels of the discovery of the Comstock lode in 1859, by O'Reilly and McLaughlin, came the invention of what is known as the Washoe process of amalgamation, by Almarin B. Paul and James Smith. On the oxidized and chloride ores of the surface it did admirable work, but, as the more rebellious material below drainage lever appeared in growing quantities, auxiliary operations required growing attention, the Augustin, Ziervogel and Patera processes, brought out from 1843 to 1858 in Europe, having been used only locally here. It was in the direction of improving the chloridizing roasting that metallurgists sought and found a solution of their troubles. Brueckner, Stetefeldt, Howell, O'Hara and others did admirable work, but with the steady improvements in lead smelting, increasing quantities of the rebellious silver ores were diverted from the amalgamating mills to the smelters, and now silver milling has shrunk to a secondary place.

Lead.—Although lead mining was begun as early as in the days of Law's famous Mississippi Company, and Mine La Motte, in Southwest Missouri, still in active operation, was discovered at that time, yet production did not develop seriously until late in the twenties. It attained about 10,000 tons per annum in 1833. With the rich and pure ores the Scotch hearth served admirably and remained the standard method until the discoveries in quick succession of the rich ore bodies of Eureka, Nevada and of different camps in Utah, late in the sixties, led to the copying of German blast furnace practice. Arents, Eilers, Hahn, Grant and others soon introduced improvements, Arents' siphon tap being a very important step forward. Water jackets appeared and a thorough scientific study of the chemical composition of slags led to more regular and cleaner working, and the collection of flue dust assumed growing importance, Iles, of Denver, doing conspicuous work in this direction. Charcoal as a fuel gave way to coke—the quantity of lead in the smelting charges needed to cover the precious metals was steadily crowded down under the pressure of a scant supply of lead-bearing ores. With the steady development of the railroad system of the Rocky Mountains, dry ores carrying little or no lead became available in larger quantities, and to-day American lead smelting plants are models for the world.

As an incident of progress in another direction may be mentioned the Bartlett process, for the direct production of white oxide for paint in successful operation at Joplin and at Canon City. In lead desilverizing and refining, a modification of the Pattinson process, invented in 1833, found only a passing application. Soon after the argentiferous base bullion of the Rocky Mountains made their appearance, the Parkes zinc process, invented in 1852, was first introduced at the Balbach works at Newark, and the most important improvement in it was that of the Faber du Faur furnace for distilling the rich zinc alloy. Since then progress has taken the direction of economic handling of large charges and the introduction of labor-saving appliances.

Copper.—Although some copper was mined along the Atlantic coast at a number of points in the eighteenth and during the earlier part of the present century, it was not until the gradual opening up of the Lake Superior region from 1845 onward that it attained the dignity of an important industry. Curiously enough, it was in the same year that the smelting industry on the seaboard was started by the Revere Copper Company and the Baltimore and Cuba Smelting and Refining Company; both depended almost entirely upon foreign supplies of raw material. These flourished for about twenty years, and then collapsed or led a precarious existence until domestic supplies of furnace material from the Rocky Mountain region caused their revival. To-day our tidewater plants are among the great works of the world, and have begun to again draw heavily from foreign sources. Thus, Australian black copper comes to us *via* London for treatment, to be returned to the European markets, and Chili bars are making the same journeys. Metallurgically, there is little to remark concerning the development in the treatment of the native copper of the Lake region, which held sway in the markets for so many decades. The time-honored methods of refining continued with little change, although effort was made to introduce the Siemens open-hearth furnace.

A new era began with the opening up of the oxidized deposits of Arizona and the ores of the Butte district. In the former the water-jacketing of the furnaces was one of the first successful steps, and a general improvement of practice followed quickly. In the Butte district a good deal of tentative work was done in concentration, in roasting and in smelting in reverberatories and in blast furnaces. The Brueckner, Brown and Wethey roasting furnaces were adopted, and the Manhes process of bessemerizing, invented in 1883, in France, was first introduced at the Parrot works. The practice has been improved very rapidly, and now the remelting of the matte is being superseded by direct transfer from the furnace to the converter. Almost simultaneously came the electrolytic process of separating the precious metals, in which very rapid progress has been made, and in which, coupled with the bessemerizing, an economic revolution has been effected, not alone in cost of production, but also in the direction of furnishing a high-grade metal from impure ores.

Iron and Steel.—And now we approach the greatest of all metals, iron, in the development of which this State has had so conspicuous a share. It would be presumptuous in me to even sketch its course, who have been a mere onlooker during the past twenty-five years, when there is with us one who has lived through its most glorious period and has had so commanding and conspicuous a part in the great deeds of American iron-makers and engineers.

After all, it was not until the days when John Fritz became a leader that the marvellous development was initiated. Remember that it was not until 1839 that anthracite was used in the blast furnace, and that six years later raw bituminous coal was tried in this country as a furnace fuel. You must recall that boiling was only introduced in 1848, that our modern steel-making processes did not really occupy a commanding position until late in the sixties, and you will realize that the great period of the iron industry is really concentrated in the last thirty years.

One fact perhaps you will allow me to dwell upon, and that is, that the Bessemer process really forced a recognition of scientific work upon the attention of the practical ironmaster. The chemist very soon became a part of the force of the steel works, and somewhat later of the furnace plants, who were anxious to have them as customers for pig iron.

Not that chemical research had not long since been directed to metallurgical operations, and not that a few did not indulge in speculations as to the scientific causes of observed phenomena.

It was only lately that I came upon striking evidence of that in David Mushet's classical work on "Iron and Steel," printed in 1840. The following passage is characteristic:

"The quality of air during the summer months becomes much contaminated from combustion; by holding in solution a much greater quantity of moisture, the abundance of nitrous particles may also diminish the usual proportion of oxygen. This will account for the inferior effects of combustion, both in common fires and in the blast furnace. It will also in a measure tend to solve the curious phenomenon of pig iron taking up less carbon in summer, although reduced with a superior quantity of fuel. The air discharged most probably contains less oxygen, yet the metal is much less carbonated than at other times when contrary proportions exist. Most probably the deficient carbon is carried off by dissolving in hydrogen, forming a constant stream of hydrocarbon gas, while the oxygen that is free unites to the iron, and while it reduces the quality, at the same time the quantity is reduced by a portion of the metal being lost in the scoria."

It is thus that one of our pioneer metallurgists seeks an explanation for the fact that furnaces are apt to make off grade irons in summer—a phenomenon which is said to have become a marked one in this boom year 1899.

Recent history in the branches of the mechanic arts records many instances of the powerful aid which theoretical investigation has offered to them. One of the most conspicuous was von Ehrenwerth's heat calculations in connection with the basic Bessemer process, which established the role which phosphorus is capable of playing as a substitute for silicon as a heat agent. Nor should that promising field be overlooked which microscopic investigation holds out. Possibly in that respect twenty years since our groping may appear not unlike that which Mushet's appears to us now.

But progress during the last seventy-five years has been pushed along lines as important in their way, as the cheapening of product, or the raising of the standard of quality. Like in other industries, the captains of ours have displayed increasing care of their armies of men. It has become an axiom with every enlightened manager that every means which shall render more satisfactory the surroundings of the workers is bound to tell upon the results of their labor. Compare our modern plants with those of former decades, of which some even survive now, and note what attention is paid to make the conditions under which manual labor is performed as tolerable as the circumstances will permit. There has been a tremendous improvement in this direction, and it does not lessen the achievement when we frankly acknowledge that it is largely due to the recognition of the fact that progress in this direction pays handsomely.

Let me go a step further, and that is, that the crowning glory of the efforts to improve our mining and metallurgical industries has been that they have contributed their full share to the development of this materialistic age. They have helped to bring within the reach of an ever-growing circle of people not alone the necessities, but also many of the comforts and some of the luxuries of life. Let me confess that it seems to me the greatest and most commendable of achievements to raise ever so little the mass of humanity in civilization, and that is what progress in the mechanic arts during the past century has accomplished in a striking manner. Start the masses on a higher plane—level them up. The great genius may not tower so far above them as once he did, but that is again in harmony with our democratic institutions. Let there be an increasing equality of opportunity, even though it makes the struggle fiercer and fiercer, if only public conscience will demand with sterner emphasis that the means for achievement be fair.

It was the keynote of Franklin's life that all his thoughts and all his endeavors were directed to making his work of benefit to the human race. Although those who have labored in our fields may not have done so as consciously or as deliberately as he, the fact is that progress in mining and metallurgy has powerfully contributed toward that end.

Anniversary Meeting of the Mechanical and Engineering Section.

INTRODUCTORY ADDRESS.

By **Wilfred Lewis**,
President of the Section.

Members of the Mechanical and Engineering Section, Ladies and Gentlemen :

For seventy-five years the Franklin Institute has devoted itself assiduously to its well-known object, "the promotion of the mechanic arts," but in the performance of this great work it has realized at various times the advantages arising from the concentration of effort along certain lines within its broad and liberal scope.

WILFRED LEWIS.

The constant subdivision of scientific thought into branches whose bounds are more and more rigorously defined is an index of the progress of our age, not that there are more different kinds of science to be studied, but because the fields of research and investigation have so expanded that the human mind is overwhelmed by the vastness of the whole, and individuals must be content to master thoroughly one small corner of a general division.

The Chemical, the Electrical and the Mining and Metallurgical Sections were consequently formed to meet the demand for more restricted bounds within which the specialists in these departments could carry on their work.

These sections are firmly established and their valuable services have been appropriately commemorated here to the honor of the Franklin Institute. They have records upon which they can look back with pride, and futures full of promise, but the work of the Mechanical and Engineering Section, which I have the honor to represent this evening, has only just begun.

About a year ago, it was suggested that a section of the Institute be organized which would appeal directly to the artisans, mechanicians, draughtsmen, designers and engineers, who form so large and important a part of our population. It was not intended to encroach upon the fields now occupied by the national and local engineering societies, whose members are for the most part engineers in active practice, but to form a society more democratic in its scope, which would welcome all who are interested in mechanical pursuits, regardless of their skill or attainments. Skilled and unskilled mechanics, novices and past masters in engineering were to have a common meeting-ground, where all might be heard, and it was hoped that in the meeting of earnest workers thus brought together, theorists would learn much to their advantage from the more practical men of action and manual skill, while the latter would be equally benefited by a deeper insight into the methods and principles of engineering.

The proposition to organize a section devoted in this way to the interests of the various mechanical pursuits at once met with favor, and the Board of Managers, at its stated meeting of November 9th, 1898, authorized the formation of a "Mechanical and Engineering Section." The inaugural meeting of the section thus authorized was held December 15th, under the leadership of Mr. James Christie, Chairman of the Committee on Sectional Arrangements, and Chief Engineer of the Pencoyd Iron Works, which has so recently astonished the world by its successful competition with England for the construction of the Atbara Bridge in Egypt. Under his guidance the section sprang at once into active life and work, and there are now enrolled upon its list of members 188 active men, as the nucleus of an organization which cannot fail to be a power for good in this and other communities.

Although not at once a large society, our numbers are, nevertheless, encouraging as a part of the Institute, embracing as it does only 2,000 members, from which we must draw recruits, and we confidently hope to grow as the advantages of membership become more generally known.

To become a member of any section, one must be a member of the Institute, in good standing, and to be such a member it is only necessary to pay the small annual dues, in return for which such abundant returns may be enjoyed.

But it is my purpose to deal more particularly with the work of the section to which this evening is devoted, and to lay before you our special claims to consideration. Every industrial establishment in the city should be interested in our success, and our members would be counted by thousands and tens of thousands if the vast army of workers could be made to realize the helpfulness of mutual education by actual contact with fellow-workers in the same field of interest.

At the inaugural meeting, a code of rules was adopted, similar to those in force in the other sections. The selection of subjects for discussion was placed in the hands of a committee on information, who decided to devote the first stated meeting to Personal Reminiscences of Changes in Machine Design and Shop Practice. This proved to be an almost inexhaustible subject, and much interesting and entertaining information was elicited, some of the members going back fifty years, to the time when railroads and steamboats were in their first stages of development. Since then we have taken up the following subjects, the discussions of which have been reported in the *Journal:* "Traveling Cranes," "The Mechanical Applications of Compressed Air," "The Construction, Operation and Maintenance of Pumping Machinery," and "Hydraulic Transmission, Valves and Packing."

In addition to the regular meetings, at which the above subjects were considered, a special meeting was called in February, to hear an address by Prof. Wm. S. Aldrich, on the U.S. Repair Ship "Vulcan," which played so important a part in the recent war with Spain. Prof. Aldrich was the Engineer-in-Charge on this remarkable vessel, and his lecture, amply illustrated by lantern slides, was full of interest.

The inestimable value of facilities for repairs at sea was clearly demonstrated, and in this was seen the immense latent strength of American forethought and mechanical genius. All honor to the men behind the guns, but they are powerless unless behind them stand the mechanics and the engineers who furnish the munitions of war with which swift and terrible execution can be accomplished. We have shown to the world our undaunted valor, energy and power to destroy, and we are now showing in a greater degree our power to build. Construction, rather than destruction, is the gauge of our real strength, and to none does the nation owe its supremacy more than to its mechanics whom the Franklin Institute has fostered and encouraged for seventy-five years.

But it is not for me to speak of the history of this noble institution, which has been aptly styled a "democratic learned society," and it would be presumptuous to make such an attempt in the presence of one who has been so long identified with its achievements—an engineer of international reputation, who has honored the Institute by his devoted service, and who has been honored in return by the highest office it could bestow—one who has labored for the enlightenment and prosperity of mankind like a true disciple of the immortal Franklin, and whose latest work has put Niagara in chains to serve our needs with the vast power that would otherwise be squandered. It is hardly necessary for me to introduce Dr. Coleman Sellers, who will now address you on "The Progress of the Mechanical Arts in three-quarters of a Century."

THE PROGRESS OF THE MECHANICAL ARTS IN THREE-QUARTERS OF A CENTURY.

By Coleman Sellers, E.D.,
Professor of Mechanics, Franklin Institute.

I have listened with interest to the remarks of the President of this section, Mr. Wilfred Lewis, in regard to the advantages which have resulted from the formation of the several sections within the society, by which those members forming the respective sections can associate and effect an exchange of opinions on matters of common interest, apart from the regular meetings of the society at large.

In looking back to the time when the Franklin Institute celebrated the first half-century of its life, I recall the speakers on that occasion, and regret exceedingly that some are unable to take part in the present celebration. I had the honor at that time to be President of the Institute and presided at the meeting held in Musical Fund Hall. Among the speakers was Mr. Frederick Fraley, who delivered the historical address, he being one of the two survivors of the original founders of the Institute. Mr. Fraley is still with us, and is now the only survivor of those few men who had the good of the mechanic and craftsman at heart when they established what has proved to be among the most successful in its practical results of all institutes of the kind in the world. I regret that the condition of Mr. Fraley's health prevents him from being able to address you at this time, but I know that in heart he is with us, as he has been for the past three-quarters of a century.

The scope of the subject upon which I have been asked to address you merits careful preparation in order to present it in a sufficiently comprehensive shape for the limits of a single address. I regret extremely that I have not had an opportunity for such preparation, and can offer, therefore, some informal remarks only, covering a few recollections and observations on the progress of the mechanic arts during the past seventy-five years. The records of the Franklin Institute are the records of much of the progress made during the whole of this time, and in the volumes of its *Journal* you will find abundant evidence of the good work of the earnest mechanics, engineers and teachers who have come together for mutual benefit and in the interest of this society. You will find no better place to note the progress of the mechanic arts than in the account of the work of these citizens of a great manufacturing city in the reports of the committees of the Franklin Institute, and especially the Committee on Science and the Arts, which for many years performed gratuitously what is now largely confided to paid experts. These men did this work of the Institute, and are still doing it, for the common good, without any expectation of other reward than the satisfaction of unselfish interest in mechanical progress.

The greatest advance in mechanics has been manifested since the advent of the locomotive. It so happens that the birth of the modern railroad system is coincident with my own birth. At that time the first railroad was put into operation in England, which development, taken in connection with the advent of the steamboat which preceded it, was certainly the exciting cause of the great industrial advance that has since been made. Previous to 1827 wooden rails had been laid to form roads over which ore was hauled from the mines, and coal was transported in the same manner by animal traction to better advantage than over common roads. Oliver Evans in our own country, and other engineers abroad, had conceived the idea of the high-pressure steam engine, and, with the full understanding of its value, a practical traction engine to use on roads was one of the first examples of its application. It was after the invention of the road engine that the locomotive upon rails became possible.

The traction engine applied to the railroad was the basis of our present wonderful system of inland intercommunication, and its development has given an impetus to all trades. In fact, the wants of the railroads taken alone would have been sufficient incentive for what has since been done in the mechanic arts, engaging, as it has, the attention of engineers to produce the labor-saving tools required for the improvement and preservation of the railroads and equipment, including the great iron and steel works that supply the rails, bridges and buildings.

Special machinery has been constantly needed to render possible such industries as iron ship-building, bridge and structural work, and the appliances which have been introduced in place of hand labor throughout the industrial world.

The progress of the single industry of machine tool building has, therefore, a most important bearing on this subject, and traced through the many stages of its rapid growth, the development of this one industry would be sufficient to illustrate the progress in mechanic arts during the period in question, and especially what has been accomplished in this country.

The important relation which tools and implements bear to the mechanic arts and, in fact, to all arts and crafts, forms the subject of an interesting tradition which was published in the *Journal of the Institute* by the late Mr. Joseph Harrison, Jr. In his home at Philadelphia he exhibited a painting by Schüsselle representing a blacksmith seated at the right hand of King Solomon's throne in his great temple, to illustrate a hypothecal event during the feast given in Jerusalem at the completion of the edifice. To this feast had been bidden the various artisans who had been engaged upon the construction and decoration of the building, those who had helped to shape the gold and silver and carve the ivory and weave the costly hangings that decorated its walls. There also came, unbidden and unrecognized, the swarthy smith, who, forcing his way through the courtiers and the guard to the throne of the king, claimed recognition as the one man to whom was due the creation of the entire work, for it was he who had forged the tools without which the other artisans could have done nothing. The wise king, recognizing the justice of the claim, gave to the smith the seat of honor.

Antedating the smith of King Solomon's day and the mechanics of all times, the progress of civilization can be traced by the study of the implements used in the daily life of different races of man, and prominent in the progress of the mechanic arts must be counted the tools with which work has been accomplished.

As one instance of progress from primitive methods during the period under consideration, it may be of interest to refer to the construction of one of the first large engines that were built for the city water works in Philadelphia. There is probably no one present who can recall the fact from actual memory, but where our Public Buildings now stand there was once a smaller structure, on top of which was a tank into which water was pumped, and this water was distributed through the then small city below Broad Street by means of wooden pipes of comparatively small size. The engine used in this work was, I believe, of the Oliver Evans type of high-pressure engine, the cylinder of which was cast in New Jersey. The boring bar used in boring out the cylinder was of the crudest character, operated by hand by means of levers attached to it, so that men walking around the cylinder could propel the cutting tools, and gradually force the cutters on the boring bar, through the cylinder, until it had been turned out approximately true. After that the inner surface had to be filed to a sufficient degree of smoothness. Probably a month was consumed in this operation of boring the cylinder. As I shall take occasion to mention, the subsequent improvements in machine tools have changed the process of cylinder boring from an effort of days to the work of a few hours.

It may be of interest also to note that when the engines were erected and the boilers put in their place at this Center Square Station, the latter were found upon test to be insufficient for their purpose. Oliver Evans had specified the length of the grate bars and the width of the furnace to be used, as also the length of the boilers, which were of the plain cylinder type, but the wise men of the city government believed that they could do better by making the boilers much longer than he had suggested, and they were so constructed. Upon their failure to do the work, Oliver Evans, who was in New York, was sent for in haste to correct the difficulty. His message to those in charge, enforced by his presence afterwards, was that they must cut off 10 feet from the length of each boiler. This seemed a strange proceeding, but he soon explained to them that the extra length which they had added to his prescribed dimensions was acting as a condenser to re-convert steam into water, inasmuch as the heat of the furnace could not extend the whole length of the boilers as they had been built. Upon cutting the boilers down to their proper size so the heat could extend over their whole fire surface, they proved sufficient for their work, and continued to operate as long as this primitive water plant was in existence. I have this story from those who were living at the time.

I hope I may be pardoned for alluding here to some events in my own experience as a mechanic in order to justify my authority as a historian. From earliest childhood my interest has been led in the direction of the mechanic arts. My first knowledge of physics came from my father, through his instructions and experiments for my benefit before I had fairly passed out of the stage of infancy, for I was but seven years old when I lost so able a teacher. As a schoolboy most of my holidays were spent in his machine works at Cardington, near Philadelphia, where I had abundant opportunity to not only know what was being done at that time, but I had from my seniors the history of what had immediately preceded my personal observation.

My acquaintance with the rapid advance in the railroads of America, and in the motive power on the roads, dates from the time when the building of locomotives was undertaken in my father's shops, immediately after Matthew Baldwin had started his works in Philadelphia. When I was 19 years of age I accepted service as draughtsman in a rolling mill in Cincinnati, where rails were being made for the roads then projected through the Western States. The rails used at that time, which were called strap rails, were flat bars of iron about 3 x 1½ inches in section, with oval depressions rolled into the face to receive the head of the spikes driven through the rail to fasten it to string pieces of wood. They were punched at each one of these depressions, which marked the location of the spike hole. At that time the most common accident on the railroads was one unknown now, namely, "snake heads," as they were called, when the strap rails, by the action of the wheels upon them, would curl up, drawing the spikes from the wood, and often piercing the bottom of the car, and not infrequently killing or injuring passengers.

After my experience in the rolling mill, where I acquired a knowledge of the wants of the railroads, I was engaged for seven years in locomotive building, first in constructing engines for the Panama Railroad, in connection with one of my brothers who was the inventor of a locomotive for ascending inclined planes. The late John C. Trautwine was the Consulting Engineer of the Panama Railroad, and it was on his recommendation that these engines were ordered, in the belief that some heavy inclines would have to be overcome in passing from the Atlantic to the Pacific Ocean at Panama, although these inclines were avoided, and the engines eventually used in the construction work merely.

Subsequently I entered the locomotive works of Niles & Co., of Cincinnati, as foreman for five years until 1857, when I accepted service as Chief Engineer for William Sellers & Co., of Philadelphia, then, as now, engaged in building machine tools. Thirty years' active experience in machine tool building enables me to speak from a full knowledge of this industry and what machine tools have done for the advance of the mechanic arts. When engaged in locomotive building in Cincinnati, I introduced a number of improved methods, but was hampered continually for the want of machine tools powerful enough to do the work as I desired it done, as well as for the want of special tools not then available. At that time in the Eastern cities certain machine tools were being built with success and were doing far better work than it was then possible with tools built in a branch of the locomotive works where I was engaged. The firm of Niles & Co. had, however, some reputation even then as builders of machine tools and sugar machinery, but it was not until the retirement of the original founders of the house that the works became devoted wholly to the machine tool business. At the time I speak of, slotters, horizontal boring machines and lathes of various kinds and quality were built in America after the introduction of the planing machine, the first one of which was probably introduced into the city of Philadelphia some time about 1830.

The early machine tools were of the crudest workmanship, and most of the lathes were made partly of wood. In fact, the transition from wood to iron in the construction of machinery was in progress during the early part of this century, and the formation of the tools themselves and much of the machinery built at that time involved the conversion of structural shapes required for wooden machines into similar shapes in metal. In the first change from wood to metal, architectural shapes and ornamentation were considered desirable to make machine tools and other machinery meet what seems to us now the rather barbaric taste of those who were to use them. The same might be said of locomotives, which almost up to the sixties were elaborately decorated with paint, polished brass and scroll work. England gave us the first good machine tools, and set the example which has tended to simplicity in design. To that country we owe much that is valuable, not only in the direction of self-acting machine tools, but also in the various appliances for improving the character and quality of work to be accomplished. Thus, Sir Joseph Whitworth, one of the earliest makers of superior machine tools in England, aimed at utility and not ornamentation in the improvement of his products. It was he who introduced surface plates for producing other plane surfaces by means of the scraper; that is to say, after a surface had been made comparatively true on the planing machine, it had yet to be brought to a commercially true plane by a process of scraping off the higher projections, until, when tested by one of the Whitworth surface plates, it seemed to touch at intervals of not more than ¼ inch.

After scraping had come to be recognized as the only means of making true plane surfaces, there followed, unfortunately, a form of deception that exists, I am sorry to say, not only in America, but still more prominently in some of the copies of American machine tools produced abroad, namely, the practice of scraping the surface without any special regard to the purpose for which the operation is intended, but rather to give it the appearance of having been carefully fitted, and the surface so produced was very aptly called by the late Mr. William B. Bement, of Philadelphia, "bedquilt scraping." The parts touched by the scraper in this imitation work are very often not irregular in design, but constitute a set figure or pattern which cannot deceive the eye of those familiar with good work.

Long before the time of the International Exhibition of 1851, America had begun to take her place in machine tool building, under a clearly distinct line of thought that was for a long time not appreciated in other countries. When visiting England, in 1884, I was shown a copy of an American planer adapted to planing the stub ends of connecting rods for locomotives, there being two sets of uprights and two cross-heads with four tool-holders adjustable in position to enable both ends of two connecting rods to be planed simultaneously. The American tool from which the idea was taken has its cross-heads facing one another, and the table is speeded to run back and forth at the same rate of cut. By this means the machine is made to take a cut at each forward and backward movement of the table. The English machine had its tool-holders facing in one direction, and all four cuts were taken at one and the same time only when the table was running forward, no work being done on the back stroke. The power of the American machine was therefore double that of its English copy, all other things being equal, and the maker was astonished when this was pointed out to him.

This one example shows how difficult it is to copy the machinery of another country if the copyist does not grasp the controlling idea of the mind that gave life to the original. Instances of this are found in many other directions where American contrivances, having obtained a world-wide reputation, are less efficient in the foreign copy than in the original production.

The planing machine is an invention well within my own experience. In the beginning it had the platen, upon which the work is fixed, dragged backwards and forwards by a chain. The first planer that William Sellers & Co. purchased and put into use was one of this chain pattern, and one was introduced in my father's shops when he undertook to build a locomotive in 1834. At the time of the Vienna Exposition, where machine tools from Philadelphia were exhibited, the engineers sent by the British Government to Vienna to note the progress that was being made noticed the broad feed cut on all the planing machines, lathes and tools that came from all parts of America, and remarked upon it as "producing good effect," as "looking well," etc., as if it were for appearance only, not knowing that it was a principle that had been established in America, thoroughly understood not only by the managers of the works, but by workmen all over this country, and universally adopted as necessary to good work.

I have already referred to the slow process of boring cylinders for pumping engines. When the early locomotives were built, for example, in the Niles Works, in 1856, the boring of the cylinders was done on a 36-inch lathe with a horizontal boring bar, and without any knowledge as to the theory of boring in order to produce the best results. It always took two days to bore the cylinder of a locomotive of the size in use at that time, and I think the largest cylinders were not over 15 inches in diameter. In Philadelphia, when Baldwin's had advanced to a very large establishment, they still bored the locomotive cylinders in the same way. It was not until shortly before the Centennial Exhibition of 1876 that attention was turned towards the utilization of a theory that had obtained in limited practice some years before as to the improvement in boring metals, the idea being that the quickest and best work can be done in boring by making the roughing cut with a fine feed, removing as much metal as possible by depth of cut, and making the finishing cut with a very broad feed but light cut that would let the cutter pass through the hole to be bored as quickly as possible so as not to wear the cutting edge in passage. That principle was first introduced when Mr. Asa Whitney, of this city, discovered that chilled cast-iron car wheels could be made to compete with the best wrought-iron ones and do a greater mileage. If the wheels cast in an iron mould were not allowed to cool naturally, but taken red hot from the chill, were put into the annealing furnaces and brought up to a heat a little below the melting point, and then allowed slowly to cool, they were found to be free from all internal strains, while wheels taken red hot from the mould would burst into three or four pieces in cooling, showing that there was violent internal strain in metal cast in that way under the tension of the heavy chill on the outside of the tread of the rim. The problem of boring chilled wheels was solved by taking advantage of the fine roughing cut and coarse finishing feed. Mr. Whitney desired to have wheels made interchangeable in their fit on the standard axles, so that when a wheel was fitted on an axle at a workshop in Philadelphia, another wheel could be furnished to fit that same axle at any future time, and just as well as the first one.

When the late Mr. Hudson had charge of the Rogers Locomotive Works he applied to the firm of William Sellers & Co., to have a special locomotive cylinder boring machine designed and built, saying that he had seen a boring machine designed by Mr. Grant, of the Grant Locomotive Works, capable of boring a 19-inch cylinder in nine hours. The matter was referred to me, and when I came to calculate the theoretical time required for boring a cylinder of the size named, on the supposition that the speed of 16 feet per minute might be used in making the cuts, with a fine feed and a deep cut for the roughing cut, and a shallow cut and a much wider feed for the finishing cut, I found that the estimated time amounted in all to only three hours, and named three and a half hours as not only possible, but what might be guaranteed as the productive output of such a machine. An order was given for this machine, it being understood that it was not only to bore the cylinders, but to counterbore the ends for the clearance of the piston, to cut off the sinking head and face up the flanges at each end of the cylinder. When completed, the first test was made with a 19-inch cylinder of hard close metal. This was bored in three hours and twenty minutes, exclusive of the time of setting the cylinder, which was not much on account of the peculiar arrangement of the machine, and the facility with which the cylinder could be put in place for boring. In this case the cylinder stood still, while the boring bar travelled lengthwise, carrying the cutter head with it, and upon the two face plates of the driving heads of the machine were arranged automatic slide rests that faced off the flanges. In this design there was no guesswork, as the principle of fine feed and deep cut on roughing, with very coarse feed and shallow cut for finishing, was in common use in all operations of boring, turning and planing metals, with exact knowledge as to what result was obtainable when the possible speed of cut per minute had been predetermined for the hardness of the metal to be tooled.

Since the time when I first related the incident of the rod planer in a paper published by me in the *Engineering Magazine*, in 1892, even this tool, useful as it is, has been superseded almost wholly in locomotive works by improved milling machines. It is not my province to detail step by step the advance that has been made in machine tool building, but, as stated at the outset, I wish to make this industry illustrate the advance in the mechanic arts, and in connection with it I must call attention to the relative condition of the skilled workmen in America and in other countries. We owe much of our progress to our common school system, to our freedom from precedent and to our just patent laws. I do not wish in the slightest degree to decry what has been done abroad, for I myself have been a close student of the progress of the mechanic arts the world over, and have been only too glad to recognize and avail myself of all that is good and worth adopting, assuming at the same time that improvement is possible and absolutely necessary in many cases to adapt the machinery designed abroad to the conditions that obtain in American workshops. The tendency to standardize everything is peculiar to this country. Builders of locomotives in America adopt standard sizes and types of locomotives, and are thus able to manufacture such to great advantage. Railroads in America are willing to take from the builders what has been shown to be good and effective, and when the same kind of machine is to be duplicated many times, the maker can afford to invest heavily in special gauges and special tools that decrease the amount of manual skill required in laying out the work or working to drawings. The first time a piece of work is done, whether it be small or large, simple or complex, more time is spent upon it than after the workmen have become familiar with its construction, and certainly more time than would be required after special appliances have been invented and made to cheapen the product, especially when the men are paid for their work according to the quality and quantity turned out, and not by a fixed wage per diem. I allude to this because I know it is the custom of foreign railroads to submit to builders in England and America specifications for engines that cannot compete in economy of construction with those that are built in quantities in the way that I have just mentioned. It is the recognition of this fact that is now opening the markets of Europe to American locomotives as they are built and as they are used in America. A celebrated builder of locomotives in England told me that the rules of the Board of Trade and parliamentary regulations for the safety of the people crowded their locomotives with useless appliances. A close observer of railroad machinery, who is familiar with the principal railroads in the world, has stated that if a locomotive builder abroad is given a new problem, such as to construct a hill-climbing freight engine, or a goods engine as it is called abroad, or even an express passenger engine for mountain districts, a completed machine may be the result that is a model of strength and durability, but inaccessible in the extreme when ordinary repairs are required. It is easier to take out the cylinders in an American engine and replace them with new ones than it is to reset the valves on the type in general use abroad, where the valve chests are crowded together under the smoke-stacks as though they would never require adjustment or resetting. The persistency evinced in adhering to the crank axle in English engines, in spite of its weakness, is one of the matters not understood in this country. Give accessibility to the valves, and ready access to all the parts, and the whole engine will be better cared for by those in charge of it.

It has been the scientific methods introduced by the managers of the railroads, aided by the skill and perfect equipment in their workshops, that have made those great railway systems what they now are. They must exercise the utmost caution in all that they undertake; every alteration or deviation from adopted standards involves so many pieces that must be changed. In regard to the simple matter of making brakeshoes for the cars, and boxes for axle journals, I know from my own experience that it was not until the introduction of machines for moulding these pieces accurately that the best results could be obtained and the parts made exact and perfectly interchangeable. Every invention, whether it be in the foundry or in the machine shop, is cumulative, and has its effect upon other trades, and through our ingenuity and progress we have now reached a point when the whole world looks to America for certain work which it seems cannot be done to equal advantage in other countries.

Dr. John Anderson, then in charge of the Woolwich Arsenal, England, was sent to this country to visit the Centennial Exhibition in 1876, and besides acting as one of the judges of the machine tool exhibit, he made an official report as British Commissioner to both houses of Parliament. Prominent in these reports there will be found one on "Machines and Tools for Working Metal, Wood and

Stone at the Philadelphia Exhibition," in which the following statement occurs:

"Great Britain certainly can claim the credit of having been the birthplace of modern machine tools, and has done wonders in raising the mechanical standard of perfection, and her influence for good in the advance of civilization thereby is incalculable; but when we consider the enormously greater area of the American continent, it is a matter of vast importance that tools have taken such a hold of the American mind, which will influence the civilization of the Western world for ages to come, and will exercise a powerful effect, not only on that continent, but on Australia, China and the world generally." This, therefore, has a profound significance which can scarcely be overrated. Again he said: "The display of machine tools made by the United States was so vast that only the more salient points can be noticed in a brief report. It showed certainly that the past century has not been passed in idleness, and, judging by the enormous stride made by them during the past few years, it showed that they have been intelligent students of the best European authorities. It is true to say, however, that the Americans, as a rule, are not copyists; the inventing of clever devices and tools for saving labor seems to be their natural forte, and worthy of the old stock, probably quickened by the peculiarly favorable circumstances under which they live. It was the display made in this section which most conspicuously brought out the enormous strength of America as a producing power. More than a hundred exhibitors had each a large exhibit that commanded the admiration of all who took the trouble to examine them in detail. In this vast array were machines for all purposes, small arms, ammunition, sewing machines, clocks, watches, and all the branches of machine-making and engineering, and almost all were finished in a style superior to that of any former exhibition."

In the engineering practice of the first quarter of this century, scientific methods did not obtain. There was little technical literature to help the designer, and the best results which have made American ingenuity appreciated the world over were brought about through careful experiments and earnest effort on original lines. The history of the steam engine, so far as the American types are concerned, was clearly not the outcome of the books, for what is thus taught under the head of thermo-dynamics is really a description of what had been accomplished, rather than the cause of the development. The need of technical education was early felt, but the want was not supplied until the generosity of individuals rendered the foundation of technical schools possible. The Government cannot be looked upon to aid in such institutions in the United States as it can in England, yet up to 1884 in London there was no technical school in existence that in any way compared with those at Hoboken and Boston in this country, besides which engineering is now taught in our universities. At a dinner given to the members of the Institution of Civil Engineers, in 1884, Sir Lyon Playfair, in responding to the toast of "The Universities of Scotland," after those of England had already been discussed by able speakers, astonished his audience by refusing to speak to the toast directly, and entered a strong plea for technical education in England such as existed at that time in the United States. He said they should not look to Germany and France for the examples of technical schools, but across the Atlantic, where those speaking their own language had already put into practice what England had so long needed. While the speaker was doubtless correct as to the wants at that time in Great Britain, the technical school of South Kensington was then being organized, and the guilds of London had contributed freely toward its support. Good work had been done by this and other schools, and by the trade schools that have been established in various parts of England.

We are long past the period of empirical work. The steel makers and iron founders now depend upon metallurgists to guide them, while every well-equipped machine shop in the country must have its staff of educated men who are able to reinforce the practical knowledge of those engaged in manufacturing by exact mathematical methods that in the early stages of our profession were limited to simple arithmetic.

As indicative of the necessity of education on the part of the working classes, I have known instances in which labor-saving machinery that was cheapening the output in a particular class of hardware, when introduced in America, into England, failed entirely and brought discredit to the member of the firm who had advised its purchase. A gentleman interested called upon me afterwards and solicited letters enabling him to visit some of the industrial establishments in the United States. Upon his return from these places he told me that all that had been said about the character of the work done by the machinery in question, not only had been confirmed, but that its merits had been underestimated. He said, however, that in his opinion, it was impossible to utilize it to advantage with the workmen in England, owing to trade prejudice and trades union regulations. What the peculiar conditions were I am unable to say, but what I wish particularly to impress upon my hearers in this respect is that in his opinion the difference in the character of our workmen and workmen of the same trades in England is wholly due to the better education of the Americans, who are fully two generations ahead of those abroad. It is perfectly evident that it is impossible to raise the standard of work by means of labor-saving machinery unless the workingmen themselves will see the advantage derived from their ability to do more and better work, and thereby obtain better wages. This is particularly the case when they are called upon in this country to operate machines that do not require constant attention, but where it is possible for one man to attend several machines and earn higher wages than he possibly could if compelled to stand idly watching a machine that required but a small portion of his time to operate. There would be no inducement to contrive automatic machinery unless those who use such machinery are able without prejudice to take advantage of the saving in labor attainable thereby.

Ship-building all over the world, since the first iron vessels were launched, shows by the constantly improved output the wonderful progress in scientific knowledge, and in manual as well as technical skill. The great fighting machines for the ocean have been improved with astonishing rapidity. This year our own output in that line has for the first time been tested and found good, when handled by men of whom we as a nation may feel proud. The nations have been increasing the power of their fighting ships year by year, adding new improvements in machinery, new means of resisting attack from other ships, new guns and newer projectiles to pierce the new armor plate, and let us hope with decreasing opportunity to bring the results to actual test in battle. In our own recent experience, practice at great cost found our trained marine force better equipped for the operation of these fighting machines, and in the far East and in the West Indies our guns swept a maritime power out of existence with upon our part scarce the loss of a man.

In working iron and steel the introduction of the Whitworth forging press marked an important advance compared with the costly steam hammers, and hydraulic presses became absolutely essential in perfecting the American type of link and pin bridge construction. Some of the forgings required for the 5,000 horse-power dynamos needed by the Niagara Falls Power Company could not have been executed by means of any existing steam hammer in this country or elsewhere, and the Bethlehem Steel Company were the first to introduce this system of forging on a large scale. Forging by pressure in place of impact by hammers enables the force required to cause a given deformation of metal to be accomplished with the least expenditure of power and greater exactness, as was soon manifested in the readiness with which hollow shafts were produced. About 1893, the work at Niagara Falls called for steel rings of absolutely uniform density, having an outside diameter of 11 feet 4 inches, with a width on the face of approximately 50 inches, and a thickness of over 5 inches, which necessitated the use of a press of greater capacity than any heretofore erected. The press at Bethlehem, combined with the Whitworth system of compressed steel ingots, was taxed to its utmost to make what was needed in this case. It is interesting to note that this work was the first product of machinery introduced mainly to furnish armor plates and the massive steel forgings needed for our modern ships of war.

The plant of the Niagara Falls Power Company offers evidence enough of the remarkable progress that has been made, not only in the mechanic arts, but in the high scientific ability required to design machines that had no precedent in size or in exact requirements as expressed in the specifications predetermining each requirement as to the results to be accomplished. Thus the designers of the dynamos were called upon to guarantee an output from each unit of power with so high an efficiency that all the magnetic and electric losses in the machine would not amount to over 2½ per cent. This requirement was fulfilled, and when subsequent machines were installed, the result was even more favorable than in the first instance. The final result is the crucial test of all progress, and certainly we have in those of our industries which require mechanical skill sufficient evidence of the marvellous progress that has been achieved during the past seventy-five years.

As I have taken occasion to mention the work at Niagara Falls, which has engaged so much of my attention, it may interest those who are not familiar with the results of this undertaking to hear something further in regard to it. At Niagara Falls we had for the first time to construct a tunnel that would be adapted as a tail race to the development of 100,000 horse-power. The International Niagara Commission had decided that 5,000 horse-power was to be the unit, and the plant was accordingly laid out on this basis. It was assumed that water-wheels could be made of that capacity and could be placed 150 feet below the level of the dynamos to be operated, where, as one of the Commissioners suggested, the length of shaft would be about the same as between the propeller and engines of an ocean steamship. In the practical solution of this problem we were obliged to have similar thrust bearings to guide the shaft, but the construction of the turbines is such that the water under the upper wheel of the two in the case is made to support phase by an invention of Mr. C. F. Scott, of the Westinghouse Company.

It is a noteworthy fact that, since the first wheels were started in 1895, there have been no stoppages of more than an hour or two at the most. The plant has been in operation night and day, carrying on processes that permit of no interruption on account of the loss which would result.

I regret that I cannot discuss this subject at greater length, for the machinery and appliances installed at Niagara Falls, as well as the industries which have resulted from the development, have made the enterprise one of the important achievements of the period we have under consideration.

Reviewing the century's progress, one cannot but be impressed with the tendency to specialize all industries. It has been truly said that jobbing shops are and always will be a necessity, but that manufacturing establishments will lead in the march of improvement. Trades are becoming more diversified, and time, talent and capital are being expended upon individual machines and appliances as special which were formerly but a part of the output of single establishments. To this concentration of the best thought upon special branches of all industries we may attribute much of the progress in the mechanic arts made during the past seventy-five years, which has opened the markets of the world to the products of our industry. The influence of the Franklin Institute has played no small part in this progress, and as one long identified with its work, I extend my greeting to its members, hoping they will continue to advance the usefulness of an institution which worthily bears the name of one of the greatest philosophers that America, and the world, has produced.

Anniversary Meeting of the Physical and Astronomical Section.

INTRODUCTORY ADDRESS.

BY DR. A. E. KENNELLY,
President of the Section.

Members of the Physical and Astronomical Section, Ladies and Gentlemen:

The Physical and Astronomical Section of the Franklin Institute, brought to your notice this evening, is the youngest section which has been organized by that body, and, in fact, has not yet passed out of its first year of existence. We feel, however, no diffidence on this score, because the sciences which this section is intended to serve have already received the Institute's consideration under less specialized and divided guise. The mechanic arts themselves, for the cultivation of which the Franklin Institute was founded, are but working bees of the hive of natural science in general, and of statics and dynamics in particular. No man can design the simplest machine without some scientific knowledge, even though he does not know it by that title, and the more complex the machine, the more scientific knowledge he must possess.

A. E. KENNELLY.

Moreover, these sciences are themselves of the most remote human antiquity. Physics, in some form, however limited, must have been studied by man at every era of his existence, and we find that some practically-acquired knowledge of physical principles is even to be found in the lower animals. As for astronomy, or the natural philosophy of the heavenly bodies, it can only be second in antiquity to physics. The constellations look down upon us in much the same aspect that they looked down upon the earliest recorded times of our ancestors, and although they, too, reckon with time and change, yet by comparison with ourselves they stand out to our gaze as emblematic of immutability.

There are two peculiarities of the exact sciences, to the devotion of which this section has been created. One is that they manifest a tendency to speak in the exact language of mathematics, and the other is that difference of opinion tends to disappear upon the subjects which they adopt. Upon practically every subject which is not included in the exact sciences, except recorded history, there exists, as a rule, a great variety of opinions, and the difference of opinion generally increases with the distance of the subject from the sphere of exact science. On such questions as the Monroe Doctrine, or the comparative beauty of orchids and geraniums, or the probable future of the Chinese Empire, we may expect to find every variety of opinion and judgment. But upon the area of a circle of two feet radius, the shape of the earth, or the distance of the moon, there is practically no difference of opinion, and such difference of opinion as does exist is restricted to such narrow limits of uncertitude or precision as to the uninitiated seems trivial and incongruous. Yet we know from history that there have been times when men disputed vehemently upon all of these questions; that is to say, before the exact sciences were sufficiently powerful to annex them. We find, indeed, vexed questions and disputes in the domains of the exact sciences, but, as a general rule, these are only on matters which have thus far eluded complete measurement and systematic generalization. The law of these questions has not yet been discovered, and for this reason they are still outside the empire of exact science. As time goes on, labor achieves, and knowledge advances, these things become measured and known, whereby dispute terminates and dissension disappears. Whether we should care to live in a world where everything belonged to the exact sciences, and in which the cause and order of all things could be found in the encyclopedia, is, of course, open to debate; but it is beyond dispute that the practical unanimity of educated opinion, upon subjects included in the exact sciences, entitled those sciences to a dignity and importance that is withheld from communities of facts that obey, as yet, no recognized law.

On looking back through the history of past centuries it is impossible to avoid recognizing the fact that the exact sciences of the remote past had but very little practical application. Astronomers, while devoting their lives unremittingly to the study of the heavenly bodies, and fully impressed with the dignity of their task, cast horoscopes and predicted nativities. Physicists, such as Archimedes, occasionally performed useful services for the community; but many mathematicians, such as Pythagoras, disdained all utilitarian aims as unworthy of their study. To them, knowledge, jealous of the attention of her devotees, frowned at all flirtations with utility.

The necessities of modern civilization, however, have swept away the prejudices that encompassed and secluded scientific research. We could not maintain the fabric of existing institutions without the aid of the applied sciences.

It is very doubtful whether the existing population of cities like London and New York could even be sustained in food, if the applied sciences were in the stage of their development at the beginning of this century, before the locomotive steam engine made its appearance. Even if the necessaries of life could be carried in to the cities from the surrounding country, in sufficient quantities, by horse wagons, the cost of transportation would make city life economically impossible to a large section of the community. Without the machinery which is the outcome of applied science, our clothing, shelter and food would require all the average man's time and effort to secure for his family and himself, and luxuries would become impossibilities. The federal government of so large an area as the United States would become a practical impossibility under the same circumstances. It is recorded that in 1812, before the days of the electric telegraph, the Government at Washington did not receive the news of the battle of New Orleans until more than three weeks after the event.

The absolute dependence of modern civilized society upon the work of the applied sciences is so great that these sciences are taxed to their utmost limit. More and better machinery is needed, cheaper, simpler and more effective than existing machinery. Competition among machines is to-day keener than the competition among men, because even the most systematic men are subject to some erratic or variable impulses which reduce the closeness and keenness of their mutual competition; whereas, machines, while maintained in repair, work with a zeal that knows no weariness and a regularity that no emotions can disturb. The result is that all the engineering sciences and applied sciences generally are taxed to their utmost to supply the needs of society. These applied sciences turn eagerly to the exact sciences for fresh material to place at the public hand. In former years there was so little demand for the applied sciences that the pure sciences only gave their rejected surplus to applications. Now the demand is so great that a large amount of purely scientific work is done in the world each year, in the hope that some of the results can be made available for utilitarian purposes. The study of the steam engine for the purpose of cheapening and improving it has added enormously to the world's scientific knowledge concerning the laws of thermodynamics. The first endeavors to lay the Atlantic telegraph cable added in a great measure to scientific knowledge concerning the ocean and its doings. The study of guns for use in war has contributed largely to the stock of accurate information concerning the motion of projectiles in resisting media. Conversely, it is almost impossible to discover any new scientific fact without finding a useful purpose for it to fill. Röntgen, for example, had scarcely more than announced the discovery of his new invisible rays, when surgeons began to use them. After looking back upon the past, it is impossible to look forward without being convinced that the practical man of the future will be more of a scientist than ever. Current literature, current speech and current development all make this confession of faith. In the days that are now behind us, an inventor who had only acquired a very moderate amount of applied science, by untrained observation and experience, could, by native ingenuity, introduce great improvements in the relatively crude industrial processes of his time. In the days that are before us, however, industrial processes are becoming so specialized, so complex and so linked with mechanical processes, that an inventor must be possessed of either greater natural ability to improve the result, or must have received some scientific training. In fact, whereas it was at one time true that "necessity was the mother of invention," it is now more nearly correct to say that science and necessity are the parents of invention. Natural science is in the last analysis, only the study of natural phenomena and of their laws, and the more complex the machinery by which those laws are controlled for industrial purposes, the more intimate must be our knowledge of them.

The benefits which have been derived during the past seventy-five years—the lifetime of the Franklin Institute—from the progress of the exact sciences and their industrial applications have been numerous. They have so modified nearly every industry as practically to revolutionize it. Where, perhaps, one hundred men then labored with weary arms, one or two men now accomplish the same result with the aid of machines. The result of all this has been that the total production of communities, per worker, has been enormously increased, so that although the average hours of labor have somewhat decreased, the average purchase of a day's labor in money has increased appreciably, and its purchase in commodities has increased very markedly. The application of the exact sciences to the forces of life has made and must continue to make life easier, brighter and more comfortable to the average member of the community.

The exact sciences pour more than pure wealth into the lap of the nation that applies them. They also ennoble.

Ignorant man, the man of very limited science, is swathed in superstition; he sees a particular spirit in every natural phenomenon and a demon in every adverse circumstance. Gradually, as he learns the laws of his environment, his superstition melts away, more intimate appreciation of the nature of the universe raises him mentally and morally, while the greater control he obtains over the processes of nature, the higher the elevation to which he rises. The average man of the community to-day possesses much more scientific knowledge than did the average man of past centuries. The average man of the community to-day is better, brighter and more comfortable, for his knowledge as well as for his power. Acquaintance with the laws of the universe, which cannot falsify, unconsciously teaches truth to all those who learn them, while the capability of being able to transport material from New York to Chicago in twenty-four hours, and the ability to converse over the same distance by telephone, is a partial apotheosis of the entire race in which the ability resides. Every new achievement of this kind which science brings within our grasp elevates humanity to a higher and nobler plane, and every earnest worker necessarily contributes to the elevation of his race.

It is, then, to the applied sciences of the future that we must look for the advances that are to make the world happier and greater than it is to-day. The result must come if no cataclysm intervene; for the forces of civilization, once given headway, are self-supporting and inevitable in their tendency. The applied sciences in their turn look to the exact sciences for development and support. The fostering and development of scientific training, knowledge, skill and application, is of vast importance to the community at the present time. That country and race and language must predominate in the world by which the natural sciences are most abundantly applied. There are no public institutions, except the hospital for the care of the sick, and the school for the education of the young, which are of more importance to the community than institutions which, like the Franklin Institute, cultivate the knowledge and application of the natural sciences.

SOME NOTABLE CONTRIBUTIONS OF AMERICAN PHYSICISTS DURING THE LAST THREE-QUARTERS OF A CENTURY.

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The cheerfully optimistic spirit which, fortunately, prevails everywhere and always among the masses of the people, easily and naturally leads to the conclusion that the present age is the golden age. Of all times in the history of the world, NOW is the most important. Never so much wisdom as now; never so much wit and courage and beauty as now; never so many things that make life worth living as now. So it was one hundred and two hundred years ago and so it will be one hundred and two hundred years hence, for the delightful disposition to accept things as they are, and not only to accept but to approve and admire, is a large and important element in that wonderful resilience which enables the human race to smile at discouragement and defy disaster. Moreover, it is a logical acceptance of evolution; an unconscious recognition of a development from worse to better, on the whole, steady and persistent.

But when one makes even a superficial examination of the centuries that have preceded our own, notwithstanding the meager knowledge we possess of some of them, it is immediately evident that such a view of existing conditions has not always been sound. It is at once seen that the progress of the race has not always been steady; that it has sometimes and for considerable periods inclined towards the worse, rather than the better, and that certain centuries stand in marked contrast with others when measure is taken of the intellectual growth and material development by which mankind has been most profoundly affected. It is this fact which gives one whose life has been wholly in the nineteenth century courage to declare that the cycle of years now coming to an end is enormously more significant in its determination of the relation of men to each other and to the universe in which they live, than any that have gone before. Indeed, it is but conservatism to declare that the nineteenth century, along certain lines of development, especially those relating to the physical condition of man, must be credited with achievements beyond those of all past time. Argument in support of this proposition has become almost commonplace, and a brief reference to a few of the more striking illustrations will be sufficient, as it may also be necessary, to create a just appreciation of some contributions to this splendid evolution which will presently be considered.

One of the most notable transformations wrought during the century is found in improved locomotion, including the transfer of goods. We do not know who invented the wheeled vehicle. It was probably in use in prehistoric times. Nor do we know who first tamed the beasts, thus substituting the muscular energy of animals for that of men. But we do know that from that remote period to the end of the first quarter of the nineteenth century, nothing essentially *new* in the way of locomotion on land was invented. The coach in which George Washington rode differed only in details of construction from that chariot into which Joseph stepped, "arrayed in vestures of fine linen," and its motive power was the same. We do not know who first spread a sail to catch the power of the wind for propelling a boat, but we do know that, previous to the nineteenth century, no ship was ever driven otherwise. It is doubtful if the speed of travelling on land and sea was materially greater in 1799 than a thousand years earlier, although improved roadways and larger vessels lessened the cost per ton mile of freight. How startling is the contrast of these methods of locomotion, the total result of thirty or forty centuries of effort, with the accomplishments of the last three-quarters of the nineteenth century. But far more amazing is the revolution which has taken place within the same period, in the methods of conveying intelligence from point to point. The telegraph and telephone could hardly have been conceived by even the most imaginative of those whose day preceded ours, and their influence upon the social and material conditions of men is yet far from its maximum. One of the most pregnant discoveries of all time was the art of controlling fire. The use of flint and steel for its production, which comes to us from the remote past, was still general during the first quarter of the century and many people are now living who were accustomed in their youth to "borrow" fire from their neighbors, in the absence of any means of creating it. The artificial light of the early part of the century was produced by methods not essentially different from those in use for thousands of years, the first real advance being the improved draught of the Argand burner. The clothing worn by our revolutionary forefathers was generally woven on hand looms and the parts were stitched together by hand, the whole process of production not differing materially from that of the "coat of many colors." During the earlier years of the present century, the harvest was gathered just as it was in the days of Ruth, and the several processes by which grain was converted into bread had altered little in thousands of years.

All of these are matters with which everybody is concerned, for food, clothing, fire, light and the means of bringing supply and demand together may be said to constitute the minimum requirements of human existence. In all of them the marvellous work of the nineteenth century overshadows that of all that have gone before.

One of the most important and suggestive books of recent publication is entitled "The Wonderful Century," by Mr. Alfred Russell Wallace, the distinguished English naturalist, who shares with Darwin the honor of conceiving one of the two most notable generalizations of modern science. In this work Mr. Wallace attempts an estimate of the value of the achievements of the nineteenth century as compared with those of all the centuries that have preceded it. In his summary he includes great inventions and discoveries in both pure or theoretical and applied science. In all he enumerates thirty-nine, of which twenty-four are to be credited to the present century and fifteen to all previous time. While in the specific selection of these epoch-making events there is much room for difference of opinion, there cannot fail to be a general agreement as to the net result. The nineteenth is truly the "wonderful century," and whatever the twentieth or the twenty-first or the twenty-second may bring forth, this verdict is not likely to be reversed.

In reviewing the achievements of this century it is found, further, that by far the largest part of this industrial and social revolution has been enacted during the past seventy-five years, that is, during the life of the Franklin Institute, the seventy-fifth anniversary of the founding of which is now being celebrated. That it may justly exhibit pride in its long and illustrious career no one will deny, for its activity during this memorable period has contributed in no small degree to the large share which our country has had in the making of modern civilization.

My own duty on this most interesting occasion, as assigned to me by the Committee of Arrangements, is the presentation of a sketch of the progress of the science of physics during the period covered by the life of the Institute. The difficulty of the task which I have undertaken will be appreciated when I remind you of the fact that it is to discoveries in physical science and their application in invention and construction, that we owe by far the larger share of what goes to make this period unique in history. Indeed, it would be a task utterly impossible in the time to which I must restrict myself if I were to attempt anything like a general treatment of the subject. Even a limitation to a review of the contributions of American physicists to the progress of the science during this period would still constitute a performance impossible under reasonable conditions. I am compelled, therefore, to confine myself to what will be the merest outline of the work of a comparatively small number of those eminent men, living and dead, who have conferred honor upon their country by their splendid contributions to physical science. I ask your indulgence and sympathy in attempting what cannot fail to be an utterly inadequate survey of a large field, and I wish especially to emphasize the fact that I make no pretense of thoroughness or of even enumerating all of those who would be justly entitled to mention in any other than a hasty sketch.

Natural science in the nineteenth century may boast of two great generalizations, of the conception and proof of two great laws or fundamental principles, against which the past might put the establishment of the Copernican theory of the solar system and the discovery and proof of the law of universal gravitation. One of them has been proved by observation, the other by experiment. The latter is the principle of the Conservation of Energy, which has been found an unerring guide in physical research. With the early history of this principle a countryman of ours had much to do. To an American, yet not an American, Count Rumford, is generally given the credit of being the first to fully realize and to distinctly announce the true character of heat as a form of energy. Driven from his home in New England by the cruel—and now believed to be absolutely unfounded—suspicions of his neighbors, he left his country only to return as her enemy, and while we have for a century profited by his subsequent generosity, we cannot fairly put his brilliant career as a scientific man to the credit side of our account. Barring Rumford's share in the principle of the Conservation of Energy, which is everywhere admitted to be large, it cannot be claimed that American physicists contributed largely to its establishment, at least not directly.

But in that domain of physical science comprehended by the term Radiant Energy, the contributions of American scholars during the past seventy-five years have been of first rank. Among the earliest workers in this field, and in many respects the most eminent, was Dr. John William Draper, and it is an interesting fact that his first scientific papers were published in the *Journal of the Franklin Institute*. Although an Englishman by birth, Draper was a loyal American from the time he took up his residence in this country at the age of 21 years. While an undergraduate in the Medical College of the University of Pennsylvania he began to display remarkable talent for original research, and his first paper "On the Nature of Capillary Attraction" was published in the *Journal* of the Institute in 1834. In 1835, before receiving his degree, he published in the same journal his first paper on light, being an account of experiments to determine whether or not it exhibited any magnetic properties. During his long life of threescore and ten years he was a most industrious investigator and voluminous writer, but his most important work in pure science had to do with light. In this he anticipated many of the results of later researches, although due credit has not always been given him. He was one of the first to examine the influence of light in producing chemical changes and was among the pioneers in the science and art of photography. The first photographic picture from life was made by him, the face of his sitter, who was his own sister, "being dusted with a white powder." On a bright day a picture was secured in five to seven minutes. He also made the first photograph of the moon. As early as 1834 he had attempted, but without success, to photograph the fixed lines of the solar spectrum, and in 1837 he began a notable series of researches on the nature of rays of light in the spectrum, and with the splendid discovery of spectrum analysis his name must always be associated. In the course of this investigation he anticipated several of the fundamental discoveries of Kirchhoff, made public by him in a celebrated memoir thirteen years later than that of Draper. His paper, "On the Production of Light by Heat," was printed in the *Philosophical Magazine* for May, 1847, and in it he declared that he had established, experimentally, the following important facts:

All solids and probably all liquids become incandescent at the same temperature.

The rays emitted by solids from common temperatures up to nearly 979° F. are invisible; at that temperature they are red, and the heat of the incandescing body being made continuously to increase, other rays are added, increasing in refragibility as the temperature rises.

Whilst the addition of rays so much the more refragible as the temperature is higher is taking place, there is an augmentation in the intensity of those already existing.

The spectrum of an incandescent solid is continuous; it contains neither bright nor dark lines.

These proportions are almost identical with those published by Kirchhoff in 1860, and upon which the spectrum analysis is founded. Had Draper made no other contributions to physics, his memoir of 1847 would have entitled him to high rank. But, in addition, he was the first to discover that in the ultra violet part of the solar spectrum there are absorption bands similar to the Fraunhofer lines of the visible spectrum. He studied the chemical effects of the different portions of the spectrum, the distribution of heat in the diffraction spectrum, the action of light on the growth of plants, and made many other researches which cannot even be mentioned here. He suggested, as a standard of photometry for white light, a piece of platinum foil of given area and thickness, heated to incandescence by an electric current of specified strength, thus, in fact, anticipating the incandescent electric lamp of Edison, and in a general way many proposed photometric standards of later date. Dr. Draper's tremendous intellectual activity was displayed in many fields and he is perhaps more widely known as the author of historical and controversial works than as a physicist. His "History of the Intellectual Development of Europe" is quoted with that of Buckle, and his "History of the Conflict Between Religion and Science" has passed through more than a score of editions in English, has been translated into nearly every known tongue, and was honored by a place in the "Index Expurgatorius," along with Galileo, Copernicus and Kepler.

Almost contemporaneous with Draper was Lewis M. Rutherfurd, whose scientific researches were also mostly made in the city of New York. Mr. Rutherfurd devoted much time and energy to the development of celestial photography, besides making important contributions to our knowledge of the solar spectrum. He constructed a spectroscope with six large bisulphide of carbon prisms, using many ingenious devices for overcoming the many difficulties which the making of an instrument of such dimensions involved. Among these was the now well-known arrangement for adjustment of the prism to the position of minimum deviation for rays of different refragibility. The application of the photographic camera to this instrument resulted in a magnificent map of the solar spectrum, especially of that part extending from F to H, which was for a long time unequalled. His experience in the production of this photograph led him to undertake the making of a diffraction grating, with which he believed he could obtain more satisfactory results. The gratings with which the memorable researches of Fraunhofer had been made were of fine wire, varying in diameter from about one-twenty-fifth to about two-thirds of a millimeter. The grating space distances between the center of the adjacent wires ranged from somewhat more than one-twentieth to seven-tenths of a millimeter. With instruments so crude as these, Fraunhofer had measured the wave length of a few of the most prominent spectrum lines with an accuracy which must command our highest admiration, but he had practically exhausted the possibilities of a wire grating. Nobert had devised a method of ruling fine lines upon glass, but his secret was carefully guarded. Although capable of ruling lines very close together, the inequality of spacing which they almost invariably exhibited greatly lessened their value for optical researches. As early as 1863 Rutherfurd attacked this problem and with such success that, as a result of his own efforts, supplemented as they have been by the later work of Rowland, American diffraction gratings have been, and are to-day, incomparably superior to those made elsewhere. In Rutherfurd's first ruling machine the movement of the plate upon which the lines were ruled was accomplished by a system of levers, but a screw was soon substituted for this, on the suggestion of Professor Rood. With the new machine gratings were ruled upon glass and also on spectrum metal, the most perfect examples being of the latter type. As many as 17,000 lines to the inch, the lines being nearly an inch and three-quarters in length, were ruled with a perfected machine and with a uniformity of spacing previously unheard of. Indeed, the diffraction spectrum was seen as it had never been seen before. Physicists were now enabled to make accurate measures of wave length with even faint sources of light, and were thus put in possession of a new instrument of research of great value.

In this connection, mention should be made of Mr. Chapman, Rutherfurd's skilful assistant, who contributed much to the final triumph by his mechanical ingenuity and patient industry. Rutherfurd was a member of the National Academy of Sciences and other scientific societies. He was extremely modest and apparently indifferent to public recognition, and as a result his excellent work has not received that notice, either at home or abroad, to which it is justly entitled.

No account of the contributions of American physicists to our knowledge of spectrum analysis would be complete without mention of important investigations made by Dr. Wolcott Gibbs, now President of the National Academy of Sciences. Although a chemist rather than a physicist, Dr. Gibbs's researches have often led him into the domain of pure physics and his work has always been of the first rank.

Ignoring chronological order, it will be most fitting to refer, at this point, to the admirable investigations in the field of optics by which Rowland has contributed to the renown of American science. The scientific importance of Rutherfurd's improved gratings, and the interesting results growing out of their use, encouraged others to attempt the construction of ruling engines which should be still more perfect, for even Rutherfurd's best plates revealed certain irregularities in the spacing of lines, seriously interfering with their highest usefulness. The interesting problem was to devise a process by which a screw could be cut more uniform in pitch than that of the lathe on which the cutting was done. Professor W. A. Rogers gave much time and ingenuity to the solution of this problem and had devised a method for correcting the errors of the lathe screw, by moving the cutting tool in a determinate manner. The solution was not entirely satisfactory, however, and when Rowland attacked the problem of making a perfect screw, he practically ignored all attempts to correct or allow for the errors of the lathe guide. Briefly, his solution, which was wonderfully complete, amounts to saying that a screw must first be cut as perfect as possible on the best lathe attainable and then it must be freed from errors by grinding in a long, reversible nut by which all sensible inequalities may be eliminated. Having prepared a screw in this manner, Rowland mounted it in a dividing or ruling engine and began to rule diffraction gratings. Great care was taken to shield the plate and machine from temperature changes or accidental disturbances during the process of ruling, and it is but just to say that the results were far superior to anything that had been previously accomplished. Moreover, Rowland hit upon the happy idea of ruling on a concave reflecting surface, so that the use of lenses might be dispensed with. He has enlarged the dimensions of these gratings and improved their quality to an extent no one had thought possible, and he has devised special forms of apparatus by which they may be used in photographing spectra. He has himself completed a most extensive series of photographic maps of the whole solar spectrum, on a scale enormously greater than any attempted before he made this special field his own. His gratings and photographic methods in the hands of other observers have been the means of adding greatly to our knowledge, not only of the solar spectrum, but of the spectra of the elements, stellar spectra, etc., and it may justly be said that no more important contribution to spectrum analysis has been made anywhere during the past twenty-five years.

In the determination of one of the most important optical constants, the velocity of light, it is universally conceded that American physicists have reached the highest degree of precision. So swift is the speed of light that it was long thought to require no time in travelling from point to point. Galileo thought it must have a finite velocity and made some experiments to determine if this were true, but without success. In 1676, Römer, a young Danish astronomer, announced to the French Academy of Science his discovery of the velocity of light, by observations of the eclipses of Jupiter's satellites, and this important fact was confirmed not long after by Bradley, the English astronomer, in the discovery of "aberration," which furnished a much more accurate value of the velocity constant than that given by the Dane. For a long time it was not thought possible to measure the velocity of light, exceeding as it does 180,000 miles per second of time, by any other than astronomical methods in which the space travelled over was sufficiently great to require a measurable period of time. In the early part of this century, however, it became very important to devise a means of measuring very small intervals of time with such accuracy as to make it possible to determine the velocity of light travelling over short distances, and the skill of the ablest physicists was challenged to accomplish this result. The difficulty of the problem will be understood when it is remembered that light will travel a mile in a little more than one-two-hundred-thousandth of a second, and if that distance could be used as the base, for the result to be true within 1 per cent. it would be necessary to measure time correctly to within one-twenty-millionth of a second. The importance of the problem grew out of the fact that the emission theory of light, as conceived by Newton, still, up to the middle of this century, had many adherents, and an *experimentum crucis* which would forever determine between that and the wave theory was greatly desired. This presented itself in the relative velocity of light in rare and dense media, in regard to which the two theories were diametrically opposed to each other. Everybody knows how Foucault, taking advantage of an ingenious application of a swiftly-revolving mirror used by Wheatstone, in an attempt to measure the velocity of electricity, completely settled the question by a beautiful experiment which he reported to the French Academy on May 6, 1850. Finding the velocity less in water than in air, the emission theory of light was compelled to yield its last foothold. But there were many other problems of great interest to be solved by more accurate methods of measuring the velocity of light and many physicists attempted to improve upon Foucault's process. The most successful of all was Michelson, a graduate of the U. S. Naval Academy, who so modified Foucault's apparatus as to insure an accuracy about two hundred times as great. In conjunction with Newcomb, America's most distinguished astronomer, he made a series of experiments which are everywhere accepted as the most refined determinations of this important constant. Michelson has since devoted most of his energy and talent to optical research, in every department of which he has met with signal success. In his invention of the Interferometer he has furnished an instrument for delicate research in light transmission productive of many very important results. In 1892 he succeeded in making a very precise comparison of the wave-length of light with the international prototype meter at Paris, the unit of length for the civilized world, and he has successfully carried out other researches in light too numerous to mention here.

Very important contributions to our knowledge of the solar spectrum have been made by Langley, Secretary of the Smithsonian Institution. They were begun at the Allegheny Observatory, of which he was director, and have been continued, being, indeed, still in progress at the Astro-physical Observatory at Washington. Langley made an important modification of Siemens's electric resistance thermometer, adapting it to the most refined problems of radiant energy, and in his hands the Bolometer, as it is called, has thrown a flood of light upon hitherto unexplored regions of the solar spectrum. He has especially explored the infra-red region of the spectrum and has been able to detect radiation of wave-lengths enormously greater than any hitherto found. He has utilized the same device in an investigation of the temperature of the moon, and in the study of sources of light apparently unaccompanied by heat. One of his most interesting researches has revealed the fact that the character of sunlight is greatly modified by absorption in its passage through the earth's atmosphere, and that the color of the sun, if it could be seen unaffected by this absorption, would be a greenish-blue.

The restrictions of the occasion will not permit of further details of these interesting investigations or of other important contributions to optics made by American physicists. It is impossible, however, to omit a brief mention of the indebtedness of American students of optics, and of scientific men throughout the world, to the exquisite skill in the production of optical apparatus possessed by two or three American artists. Pre-eminent in this field have been the Clarks, father and sons, now alas! dead, and Brashear, of Allegheny, still in the prime of a life which has been devoted to the mastery of mechanical difficulties in the way of producing optical surfaces of the very highest accuracy. The almost unique position which American physicists occupy to-day in the domain of optical research is largely due to the delicate touch and brain-directed handicraft of these men.

Equally important extensions of our knowledge of that form of radiant energy known as heat have taken place during the last three-quarters of the century, but the contributions of American physicists have not here been so notable. Much has been done, however, worthy of mention, if only time permitted, and some record must be made of work in this field not already included in the investigations of Draper, Langley and others. Rowland's determination of the mechanical equivalent of heat will always rank as a classic. Following the general plan of Joule's famous experiment he greatly improved the apparatus, giving especial attention to the change in the specific heat of water with varying temperature, and the thermometric part of the work was much more precise than that of Joule. The practical value of the result was great, and the theoretical even greater, because it has destroyed certain discrepancies previously existing among values of this constant obtained by widely differing methods.

If I had to do with applied physics, there would be much to say of the share of our countrymen in the wonderful development and improvement of heat-engines and of the enormously increased utilization of the energy of fuel, but this phase of the question I must not touch.

In that department of physics of which but little was known a hundred years ago—electricity and magnetism—our philosophers have been among the first. At the close of the last century our most brilliant scholar and diplomat, Benjamin Franklin, was the world's most distinguished electrician. When this institution which bears his name was assuming form seventy-five years ago, one who was destined to be second only to him in renown as a student of electricity was just beginning a series of investigations which added great luster to American science. Of the work of Joseph Henry in electricity, most of which was done while he was still a very young man, at the Albany Academy, I may be permitted to quote what I have said in another place. His first important work was the development and perfecting of the electro-magnet. With this now commonplace but most important electrical device three names will always be associated. Shortly after the announcement of Oersted's brilliant discovery, which furnished the first connecting link between electricity and magnetism, Arago had announced the interesting fact that if rods of steel or iron were placed in a glass tube around which a wire was coiled so that the adjacent rings did not touch each other, they would become magnetic on the passage of a current of electricity through the wire. Thus Oersted's discovery, that an electrical current would *influence* a magnet, was supplemented by Arago's, that it would also *produce* a magnet. Three or four years later another notable step in advance was made by Sturgeon, in England, who produced for the first time what has since been known as an "electro-magnet." He bent a bar of soft iron into the shape of a horseshoe, thus bringing the poles into the same plane for greater convenience; and he dispensed with the glass tube used by Arago, by varnishing his iron core, thus insulating the coils of naked wire, which he wound in a spiral about it. But the most powerful electro-magnets made by Sturgeon's method were insignificant compared with what Henry was able to produce a few years later. Instead of varnishing the iron core and using naked wire, he insulated the copper wire itself by covering it with silk, and this enabled him to coil the wire closely and to make two or more layers about the core. This had the effect of enormously increasing the strength of the magnets produced, and Henry at once recognized the importance of the discovery. But he carried the investigation much further, examining into the relation of the battery to the magnet, developing two forms of the latter, which he called "quantity" and "intensity" magnets, and by the aid of the latter succeeded in making visible and audible signals at the end of a long line, which had been declared to be impossible by Barlow.

He actually set up in the hall of the Albany Academy a line more than a mile in length, through which signals were transmitted without difficulty, and the principles involved were so well understood by Henry, that even then—in 1832—he confidently declared that transmission through any reasonable distance was possible. This system was the germ of all modern telegraphy. At about the same time its development in Europe began; but at first and for many years all European systems were based on the phenomenon discovered by Oersted—the deviation of a needle on the passage of an electric current through a conductor near and parallel to it. While Henry was exhibiting his perfectly conceived and well-executed scheme for electric transmission to visiting friends, Baron Schilling, a Russian Councillor of State, set up a model of his proposed electric telegraph before the Emperors Alexander and Nicholas, the first of the many "needle" systems which prevailed in Europe for many years, but which were finally driven out by the superior merits of the American system. Schilling's telegraph required thirty-six needles for its operation, besides a complicated device for an audible signal to attract the attention of the operator.

In connection with his study of magnets, Henry also devised what is now generally known as a "relay," which is an arrangement by means of which an electro-magnet operated by one current is made to close the circuit of another battery, thus enabling a feeble magnet, requiring only a feeble current, to set into operation another at any point in the circuit. Thus he had evolved all the essentials of a complete telegraph system, lacking only mechanical details which engineering skill and ingenuity might easily have supplied.

Had Henry been less a lover of pure science, or had his commercial instinct been more highly developed, the Albany Academy mile of wire would have grown into the telegraph system of America, instead of furnishing, as it unquestionably did ten years later, the principle upon which that system was founded. It has required a good many years to dispel certain illusions concerning the electric telegraph to which Americans were inclined to cling, but it is now tolerably well known among intelligent people that the first commercially successful electric telegraph line was *not* erected in this country; that the telegraph can in no sense be called an American invention, although the American system has proved to be so superior that it has long ago practically superseded all others; and that by far the larger share of the credit for the success of this system is due to Joseph Henry for his discovery of the scientific principles upon which that success depended.

In the meantime Henry was engaged in further researches of the very highest importance. He sought to use the powerful magnets which he was now able to construct in the solution of a problem which had thus far baffled the efforts of the ablest electricians in Europe. Having succeeded beyond all others in *producing* magnetism by *using electricity*, he hoped to be able to successfully attack the inverse problem, the *production of electricity from magnetism.* All physicists believed that this must be possible, but no one had hit upon the method of doing it. Curiously enough, another great experimental philosopher, also a young man, had set for himself the same problem and worked persistently upon it during the month of August, 1831. During the same month Henry began a carefully planned series of experiments, which unfortunately, owing to his duties in the Academy, he was obliged to give up, not being able to return to them for nearly a year. Entirely ignorant of Henry's plans, Faraday, on the 30th of August, 1831—a memorable day in the history of electricity—made the capital discovery of *induction*, on which practically all modern electrical development is based. Entirely ignorant of what Faraday had done, Henry again took up the subject and had the good fortune to discover the identical phenomenon in another aspect, in which it is known as *self-induction*. In the more recent advances in applied electricity, self-induction has come to be a matter of primary importance, and time has served only to magnify the value of Henry's discovery. Learning of Faraday's experiments, he was led, through their verification, to discover induction by induced currents, concerning which he made a most interesting and valuable investigation. Of his many other important discoveries in electricity there is one that must not be passed without mention. It was that the discharge of a Leyden jar was oscillatory in character, in which he anticipated Helmholtz and Lord Kelvin in the recognition of a phenomenon which has, within a very few years, come to have a deep import. The present estimate of the value of Henry's work in electricity is reflected in the following remarks, made not long ago by one of England's leading electricians: "At the head of this long line of illustrious investigators stand the names of Faraday and Henry. On the foundation-stones of truth laid down by them, all subsequent builders have been content to rest * * * * In them (the scientific writings of Henry) we have not only the lucid explanations of the discoverer, but the suggestions and ideas of a most profound and inventive mind, and which indicate that Henry had early touched levels of discovery only just recently becoming fully worked."

In the study of Terrestrial Magnetism, the great work of Bache, begun in Philadelphia and continued with important extension in the United States Coast and Geodetic Survey, of which he was the most famous superintendent, is worthy of the highest praise. The work of Rowland in electricity and magnetism has been of much importance, and especial mention must be made of his beautiful experiment in 1876, in which he showed that a magnetic needle was affected by a rotary disc carrying an electric charge, and also of his redetermination of the value of the ohm at a later date.

It is again difficult to resist the temptation to discuss the practical applications of electrical discoveries, for in this field it may justly be said that our countrymen have outranked all others. It would be a pleasure to relate something of the labors and successes of Wallace, the pioneer in the production of strong currents by the use of a dynamo; of Brush, who first solved the problem of arc lighting; of Edison, whose ingenious inventions in duplex and multiplex telegraphy have been eclipsed by his creation of the incandescent system of electric lighting; of Bell, whose beautifully simple device for the electric transmission of human speech startled the world in 1876, and has since all but revolutionized the conduct of the ordinary affairs of life; and of others who have contributed during the last quarter of a century to put the United States far in advance of all other countries in the application of scientific discovery to the improvement of the condition of mankind.

In other departments of physics American scholars have also had their share. In sound, important researches were made by Henry, and beautiful experimental investigations were carried out by Mayer, leading to important results. In meteorology, which is physics applied to the atmosphere, the names of Espy, Loomis, Ferrel and Abbe are everywhere known. The work of the Coast Survey in Terrestrial Physics, including magnetism and gravity, is universally admitted to be of the first order. In the application of physics to astronomy, American scholars easily rank with the highest; but into these and other regions I must not go, however much drawn towards them, for, unsatisfactory as my sketch is to its author, it must be brought to an end. It has been confined entirely to work accomplished and it has not ventured to suggest what the new century has in store. Within the last ten years a new group, almost a new school of American physicists, has made its appearance. With the enthusiasm and vigor of youth, prepared by the best of training under the most favorable circumstances, great in numbers and strong in purpose, these twentieth century philosophers may be trusted to maintain the rank won by their illustrious predecessors and to add to their country's renown by the splendor of their achievements.

But it may be well to remind them that the problems which the nineteenth century passes on to the twentieth are not all related to science, pure or applied. How to use is often as important as how to produce. In spite of the enormous increase in the production of the necessities of life and the extraordinary diminution in their cost, their acquisition by the great majority of the race still means the exhaustion of their entire stock of energy. And this condition of things is being still further intensified by a steadily increasing proportion of idle, non-productive population, an element of both weakness and danger which modern civilization has thus far been unable to throw off. For the avowed purpose of keeping the peace, the world becomes a vast military camp, and it is not easy to decide whether scientific discovery has contributed most to the prolongation and betterment of human life or to the construction of improved machinery for its destruction. The cost of a single steel-clad battleship would establish, equip and richly endow a university, and the expenditure necessary to keep it in commission would maintain an institution for original research of such capacity and proportions that its output would be a never-ending blessing to all the people. Let us hope that among the glories of the twentieth century may be the recognition of the incongruity of a beneficence which seems to be founded upon the sentiment "Whom we would help let us first kill."

Anniversary Meeting of the Franklin Institute.

PROCEEDINGS OF INSTITUTE DAY.

In opening the meeting which concluded the ceremonies of the seventy-fifth anniversary, President Birkinbine spoke as follows:

Following the series of excellent papers which have been presented before the different sections by men renowned in their specialties, it falls to the President of the Institute to take charge of the closing exercises of our seventy-fifth anniversary proceedings, a duty which I am proud to perform.

Five days ago the committee assigned to me the pleasant task of opening the series of exercises, which will be memorable by reason of the valuable papers presented, and I desire to express to the able speakers who have contributed to these meetings the cordial, hearty thanks of the Institute for the interest they have exhibited and the assistance which they rendered.

Seventy-five years measured by the span of life allotted to man is a long time, and few are permitted to exceed the seriplural limit of threescore and ten years. We therefore do not rely upon personal reminiscences, but depend upon data which may be classed as historical.

Fortunately, a continuous record has been kept in the Institute's publications, and in these we trace the progressive steps in the mechanic arts and in applied science. Our publications form an epitome of the advancement made during seventy-five years in manufactures and in varied industries, and a cyclopedia of scientific development. Hence our data, although historical, are authentic, and from these we can judge the progress made during the existence of our organization.

Although announced to present an introductory address, it is not the intention to take from the gentlemen who are assigned to this evening, and I shall confine my remarks to a suggestion as to the comparative conditions existing when the Franklin Institute was organized and those with which we are now familiar by every-day contact as evidenced by the exhibitions with which it has been connected, and to briefly refer to the mission of the Institute.

A *résumé* of the progress which has been noted by those who addressed the sections would prove instructive, but this each can make for himself or herself, and it is merely commended to you.

Probably no better illustration of the advancement in three-quarters of a century could be offered than this Exposition in which the Institute has taken so much interest and which bears its name as joint sponsor with the Philadelphia Museums. With a record of twenty-nine previous exhibitions, the Institute has done well to take its place as a partner in this enterprise—an enterprise which, from intimate knowledge of details, I am gratified to announce has fully met the expectations of its management.

Our members will recall the fact that the Textile Exposition contemplated by the Institute in 1896 was abandoned because the time was considered as inauspicious, but that the Committee on Exhibitions was considering the propriety of a special exhibition when the invitation to coöperate with the Philadelphia Museums came to us. This invitation was met in the same cordial spirit as that which encouraged its presentation, and the National Export Exposition was announced to be held under the joint auspices of the two organizations.

Throughout the periods of organization and construction the two organizations have worked hand in hand and in entire harmony, and it is a great pleasure to state that to the members of the Franklin Institute much of the success of the National Export Exposition is cheerfully credited.

In previous exhibitions the Institute has sought to encourage domestic manufactures, or, as in the Electrical

Exhibition of 1885, to stimulate industrial development in a special direction. We meet to-night as a part of the first exposition to foster the extension of American manufactures to foreign lands, and in these buildings are some of the finest products of our mechanics and artisans.

The industrial revival which has characterized the past few months, while benefiting the country at large, interfered materially with the exhibition of products of some of our manufacturers, but a tour through the aisles cannot fail to impress the visitor with the magnitude and the variety of the manufacturing interests of this country.

A comparison of the Franklin Institute's first exhibition in 1824 with that of 1899 would be instructive, if we could truly picture the conditions which existed seventy-five years ago and place them side by side with those about us. The material used in constructing most of these buildings was unobtainable, and the methods employed were believed to be impossible seventy-five years ago. The rapidity with which the metal work of the building in which this meeting is held was erected would have been considered as a visionary prophecy, for the steel skeleton of this structure, 400 feet long, 90 feet wide and 60 feet high, weighing 550 tons, was, by the means of improved handling appliances and skilled labor, put in place and connected in forty-eight and one-half working hours.

The various systems of illumination which are illustrated at this exposition by installations covering large areas, are all developments of late years. The filaments forming the mantles which are maintained in incandescence by the combustion of gas, petroleum or naphtha; the films or pencils of carbon made radiant by electricity in the incandescent or arc lights, by alternating and direct currents; and the application of acetylene, are all quite modern.

The same may be said of the means of producing and distributing power. In fact, whichever way one turns he meets what would have been marvels to those who came together for the purpose of organizing the Franklin Institute; and it would be easier to recount the few things which are not to be classed in this category than to attempt to even summarize the marked instances of improvements which are about us. Having been conversant with the details of construction and equipment of the exposition buildings of 1899, the conditions which were met, the difficulties which arose and the resources which were available, the comparison of the exhibitions of 1824 and 1899 is most impressive to the speaker. The most pronounced optimist among those who assembled, in 1824, in Independence Hall, to organize an association for the promotion of the mechanic arts, could not have imagined such refinements in their application as are seen in this exposition. Had the infirmities of age not prevented our esteemed fellow-citizen, the Hon. Frederick Fraley, the only survivor of our charter members, from being with us to-night, he would have told you that the statement just made was fully warranted.

That the Franklin Institute has survived and reached the age of seventy-five years is in itself proof that it has done good work; no such organization could have lived so long unless it had accomplished good. The work which has been performed has already been referred to by speakers who have taken up different phases or specialties, and the history of the Institute is open to the world.

It remains for me, therefore, to suggest that each shall study for himself what the Institute has been and what its possibilities are. Notwithstanding the severe business depression through which the country has passed for several years, the Institute has been making constant progress. New sections have been formed which have rivalled the older ones in activity. The valuable library has been cared for in a fire-proof structure. The reading-room has been improved, the models have been rearranged, and much has been done to show the citizens of Philadelphia and of the country at large that the Franklin Institute is alive to its responsibilities; that it is doing its best with restricted facilities and very limited income to advance the mechanic arts and encourage interest in all branches of applied science. Every department of the Institute, its library, its drawing-room, its laboratories, its lectures, its sectional meetings, its Committee on Science and Arts, are active; and the members are unselfishly working for the interest of the Institute and for the advancement of their fellows.

The Franklin Institute has been before the public for so many years and its work so often commended, that it is presumed to be amply endowed with funds for continuing its efforts. Unfortunately this is not the case, and each succeeding year forces the management to face the necessity of curtailing its plans to cover new ground, by reason of an income barely sufficient, with careful husbanding, to effectively administer the work already in hand.

Under these conditions the individual efforts of each member are essential, and the burden of maintenance must be met from the annual dues. While this encourages a healthy activity, it unfortunately places limitations upon the work which can be assumed.

To overcome this disadvantage either the membership roll must be materially augmented so as to secure an increased revenue, or endowments must be secured to supplement those which the Franklin Institute now possesses, some of which are for specific purposes and, therefore, not available for the expenses of maintenance.

It is not too much to expect that the celebration of the seventy-fifth anniversary may draw attention to the Institute, to what it has accomplished, to what it is doing, and to what it desires to accomplish, with the results that its endowment funds may be increased, that its membership may be augmented, and that it will soon be able to crowd itself out of the old home into new and more commodious quarters. This is desired, not by reason of waning affection for the old home, for the building on Seventh Street is full of memories of great inventions fostered, valuable researches made public, marvelous experiments illustrated, hundreds of instructive lectures and discourses presented; and is hallowed by its association with the names of the world's great scientists. But there is still a greater work for the Institute to do; its field of usefulness should be extended, and its ability to occupy this field is hampered by restricted quarters and by an inadequate income which for years has been too small to properly maintain its reputation and permit it to expand its field of usefulness.

No better celebration of this seventy-fifth anniversary could result than that the good people of this city and State, the Municipal, and State, and Federal Government should combine to place this honored Institute in a position where it could cover a wider field, make its valuable library more useful and give full scope to its ambition to extend interest in the specialties for the development of which it was organized.

The 2,000 members of the Franklin Institute can, in a united effort, accomplish all that is here suggested, but the aid of each individual member is needed. Shall it, from this date, take a step forward? The answer rests with you.

EVOLUTION OF TECHNICAL EDUCATION

IN

ECONOMICS, POLITICS, STATECRAFT AND MORALS; THE WORK OF THE FRANKLIN INSTITUTE DURING SEVENTY-FIVE YEARS.

By Robert H. Thurston,

Honorary Member of the Institute and Director of Sibley College, Cornell University.

The ideal education of the old Greek who would teach the youth of his country "to speak the truth and to ride a horse," although by no means as comprehensive as the "complete and perfect education" of John Milton, is at least typical of the best thought of the educator of our own time; and especially is it representative, in a way, of the ideals of the advocate of the evolution of the technical education of people with a view to the preparation of the great body of "plain people" for "the sequel of their lives." The seeking of truths, of facts and data, and of methods of utilization of such truths in the interest of the people, in the promotion of their moral, social and intellectual advancement—of that material progress which underlies all—constitutes real education.

This constitutes a problem for the economist, for the wise political leader and for the statesman of every grade. For the ancient aristocrat and gentleman, honesty and ability to bear oneself as became a gentleman, in all out-of-door exercise as well as in social intercourse with other gentlefolk, were recognized as the fundamental elements of a proper training. Little more was then needed and little more was prescribed. As time went on, not simply the speaking of truth but the learning of truths, not simply the riding of a horse but all manly exercises and warlike accomplishments, were demanded as essential elements of the curriculum of the gentlemen. Later, as the arts of war became less exercised and as those of peace became more and more vitally important with all classes, the clergy of Europe came to dictate the form and extent of the education of the gentlemen and of the well-to-do classes of the time. Even gymnastic exercises as a part of the regular education fell into the background with the drifting out of sight of the arts of war, and the modern, monastic, gymnastic methods of education took shape and controlled all schools. Still later, after political power had fallen out of the hands of monarchs and nobles into the hands of the people, and it had come to be seen that the contemporary education was suited only to the wealthy and aristocratic classes, a new education came into existence, and Bacon and Descartes, Milton and the Marquis of Worcester and Vaucanson sought the development of this field by the introduction of systems of training of the people in such manner as would give them not only a knowledge of language and of literature, of history and of philosophy, but also an acquaintance with the sciences, pure and applied, and with the scientific bases, and even the actual processes, of those arts the prac-

ROBERT H. THURSTON.

tice of which must, with the great masses, occupy the entire adult and active existence.

In early historic and in prehistoric times, government, so far as developed, was simply a system of forcible control of the masses of the people with a view to the advantage of the ruler and for the purpose of securing for him means of offence and defence in his constant warfare with his neighbors. As time passed and regal power was taken from the hands of the monarch and fell into those of the aristocratic classes, the art of war was cherished largely for the same reasons as those controlling the emperors and the kings of earlier days; although the arts of peace assumed larger importance as wealth and fashion, and the always resultant luxury and effeminacy of the wealthy classes, brought into being a demand for greater intricacy of life and increasing diversification of industries; while the training of skilled workmen has constantly assumed greater and greater importance to the state. The science of economics, the true science of politics and the real and highest duty of statecraft, thus gradually came to be clearly recognized by a few great minds. Comenius and Froebel, Milton and Worcester, Descartes and Vaucanson all saw clearly the real meaning of the Greek ideal for later times, and all did what they could to introduce a broader and a better curriculum and to adapt the scheme of general education more perfectly to the needs of the people. To day, every thoughtful and well-read and experienced educator sees that a true rendering of the Greek ideal into contemporary form would dictate the education of the people for the life and work of the people, the universal adoption of manual training in public schools, the evolution of a technical side to education, which, coupled with the older gymnastic forms, should give to every ambitious youth opportunity to learn the scientific, the logical and formal, basis of the art into which he feels himself impelled by natural predilection, and sees it should include in its range, not only all the literatures and their languages, all the sciences and their applications, and all the arts of simple accomplishment, but, even more completely and thoroughly, the arts and vocations of common life, to the extent to which they lend themselves to scientific and logical methods of instruction. Only thus can a truly wise system of education of the people for the life and work of the people be founded.

To-day, the arts of war engage the attention of comparatively few; the arts of peace occupy practically the whole mass of the people. The chief duty of the statesman, of the wise leader in politics, as well as of the economist, is no longer primarily, almost solely, the study of war and of strategy, of diplomacy and of the raising of armies; it is now, rather, primarily and principally the promotion of the business interests of his country, the advancement of the arts of peace, the maintenance of those industries providing the essentials of modern civilizations, the diversification of industries for the purpose of giving larger opportunities and greater industrial and political independence to his own people, and the provision of that education, necessarily largely technical, which best meets the needs of the people as individuals and as a nation.

To-day, the acuteness of the political leader and the wisdom of the statesman may be very accurately gauged by the attention which he gives to the education of the people and especially to a systematic development of that technical education which has so long, but so slowly, been in process of evolution as a complement of the gymnastic, purely literary curriculum of older times. The moral and intellectual magnitude of the educator may be measured by the extent to which he has come to appreciate and to promote these evolutionary movements. The statesmen of Germany, of France, the educators of our own country, particularly, illustrate this fact. Glancing over the compilation of testimony favorable to the inauguration, in the earliest days of our republic, of a national university, as representative of a national and public scheme of education of the people, as printed by the national committee, one sees at a glance that the signatures are those of the greatest statesmen of their time; the grander his statecraft, the nobler his plans for educational development and the larger the measure of the man in all ways. This has been true from the days of Zenophon and of Herodotus to those of Washington and of Jefferson, and of the founders of German technical education, of our "Land Grant Colleges" and of that Cornellian system which would unite in one great institution systems of education of all men in all studies; such as would prepare the scholar, equally well and with absolutely equal honor, for the rostrum, for the pulpit and for the professor's chair, the lawyer for his courts, the physician for his hospital and for ministration at the sick-bed, the engineer for construction of railroads, canals, bridges and steam-engines and steam-boats, the farmer for all forms of agriculture and the artisan for the workshop, factory and mill. Of these classes, a thousand require scientific instruction where one depends upon literature for his support; hundreds demand a knowledge of the scientific basis of the arts where one needs tuition in language; scores seek professions having a scientific foundation where one can utilize, in later life and for his own personal advantage, the "liberal" education of the so called "learned professions."

Biblical history tells us that, in the eighth generation of the race of Adam, Tubal-Cain was "the forger of every cutting instrument of brass and of iron."* The metal-working trades were thus established, necessarily, at the very beginning of civilization, and apprenticeship, which is technical education, must have become an established system before a vocation could become a trade, before the art of the individual could become the art of a guild. Life in cities could not take form until the trades of the manufacturing industries were fully organized and the age of the cities of antiquity, of ancient India, of Assyria, of Babylonia, of Asia Minor, of Egypt, Greece and Italy, measures approximately the space of time separating us from the beginnings of manual training and of trade-instruction which are, in turn, the foundations of modern technical and professional training. When the great deluge washed away the product of the antediluvian industries, the erection of the tower of Babel was the construction, also, of a memorial to the brickmakers of the reviving world. Every modern fundamental profession, trade and vocation probably has a history approximating in its length that of the race itself. Technical education is prehistoric in source, and its history has simply been that of an originally simple and non-scientific, an empirical, system, developing by an evolution, under conditions sometimes favorable, sometimes restrictive, in such manner as to make its progress extremely variable in rate and method from its earliest to its latest phases.

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* Gen. iv: 22.

George Ebers, the famous Egyptologist, and hardly less distinguished and certainly more widely known historical novelist,* finds records amid the tombs and pyramids of the valley of the Nile indicating the existence of a great school and college system supported by the Pharaohs, fifteen hundred years and more earlier than the Christian era. For the time, indeed, it was more nearly a true university system than has been seen in Europe since that era, and hardly less universal in its breadth than that inaugurated by Ezra Cornell in the United States of North America in our own generation. Organized in the "House of Seti," in Upper Thebes, it excelled the still older foundations at Heliopolis and at Memphis in its universality, and especially in its extension of its curricula into the fields of technical learning. In its preparatory school, even, were departments of theological, mathematical, legal, astronomical and pedagogical technology. Its great library contained many thousand rolls of papyrus. Schools of art, architecture, sculpture, painting and of engineering, so far as developed at the time, insured the cultivation of the æsthetic with the useful and their union in construction. In magnitude, only Thotmes' great temple exceeded that vast pile. More than this, it was a system of free schools and colleges to which every citizen had a right to send his sons. Dormitories for the young men of the wealthier and noble classes were adjacent, and famous priests guarded and guided the pupils.

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* Professor of Egyptology at the University of Leipsic.

" Scribes"—university professors, free from other labors—were given opportunity for study and research in the highest realms of science, of literature and of art, pure and applied. Its faculty numbered above 800, and there were three " prophets " appointed as directors of its colleges, of whom the high-priest was the senior. Splendid residences were assigned the faculty, and of these that of the high-priest was of unequalled magnificence.

Its successor, the " House of Rameses," was similarly but even more liberally planned, 1300 B.C. The University of Rameses was in existence 1,000 years before the foundation of the later and possibly even greater University of Alexandria.

Technical education finds its earliest, at all complete, records, in the accounts by the Greek historians of the work performed by the technical staff of the great University of Alexandria, during the centuries elapsing between the foundation of that first most complete of universities and its destruction by the Saracens.* When Hero taught mechanical engineering and Archimedes the art of war, when Hipparchus lectured on astronomy and measured the periods of planets and eclipse-cycles, and when disciples of Aristotle gave form to a logical method, technical education took on a distinct form and became recognized as an essential department of instruction. The Alexandrian university was not only the first such great educational organization, but it was, in a true sense, the first university and, for the first time—in fact, for the only time in the early history of education—an institution properly so designated, since then and there, only, in all the course of history, up to our own time, was the endeavor made to offer instruction in all the literatures, in all sciences and in all the arts of the time. Ptolemy, in its foundation, sought to provide what Ezra Cornell aspired to organize—" an institution in which any person might find instruction in any study." Aristotle and his disciples despised no fact and respected all forms of knowledge.

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* " Intellectual Development of Europe," by John W. Draper. New York : D. Appleton & Co.

The "Museum" of Alexandria was the birthplace, as Draper has truly said, of all modern science. Other nations had earlier studied natural science; other civilizations had still earlier produced great schools and great men curious in the observation and study of natural law and of nature's marvellous operations; but it was in Alexandria and in the time of the Ptolemies that we find the earliest adoption of a correct method of scientific investigation and evidences of researches to discover fact and natural law—real scientific research, "the interrogation of nature through systematically planned and prosecuted experiment."

This first and most universal of universities—the times being considered—was founded to promote the acquisition of knowledge in all fields of history, philosophy, literature and natural science, to illustrate the methods of Aristotle, the first philosopher recognizing what we are, in our conceit, prone to designate the "modern" scientific method—first seeking facts, next deducing laws, then constructing a science by the codification of the natural laws thus revealed. The older Greek "philosophy" of the imagination was rejected, and the true philosophy of fact and sound logic and scientific deduction was brought into practice. The speculative philosopher was retired and the experimental philosopher, the scientific investigator, took place in the van. Archimedes investigated the laws of hydraulics; Ptolemy those of optics; Hipparchus gave his contemporaries and his successors, even to our own time, valuable results of research in astronomy; using instruments of precision and making exact measurements as bases for his computations. Euclid created geometry and the world still finds his work perfect. Archimedes' mathematical studies gave him pre-eminence as a leader in his department, and no rival appeared for many centuries, and even up to the time of Newton. In applied sciences, in his discoveries relating to specific gravity, in his inventions of the lever, the screw, the burning mirror, apparatus of war and of peace, he proved himself the first really great producer of the mechanisms and machinery of the engineer and the physicist. Eratosthenes was the great geographer whose work was the beginning of all that we to-day know, both as to fact and as to system; he founded physical geography. These mighty men of mind recognized the facts of the rotation of the earth, the nature of heat as a form of energy, the general distribution of light and heat, and the variations of climate throughout a spherical earth. So accurate were their astronomical measurements that Ptolemy was able to discover the moon's evection, and Hipparchus the precession of the equinoxes, measuring its period. The motions of the planets were observed and discussed, and Timocharis noted the phases and movements of Venus. Ctesibus invented fire-engines and water clocks: Hero described the first steam-engine, that form which is to-day coming in again, two thousand years after Hero, in the form of the steam-turbine, as a rival of the complicated and costly and imposing machine which is the product of an evolution having a history, as a train of mechanism, of just one century. Sosigenes of Alexandria, in the time of Julius Cæsar, went to Rome to rectify the then confused calendar, and thus this first great university, the prototype of the modern university of our own State, a university without intermediate representative in all these centuries, and which we now recognize as in fact a real and a great technical college, carried its wonderful work through the centuries immediately preceding and succeeding the Christian era.

The Saracen conquest of Egypt resulted in the destruction, in large degree, of this majestic edifice of learning; but the Saracens themselves, once the conquest was complete and they were permitted to settle down to the pursuit of the arts of peace, became inspired with the genius of investigation; the conquerors took up the work of the conquered and we now credit the Arabian philosophers and men of learning with preserving and advancing human knowledge in hardly less degree than did, in the earlier centuries, the Greek Ptolemies and their allies.

The energy of a race is like that of a river, small or great, quiet or torrential, flowing from earlier to later times, compelled by natural forces constantly to follow a general direction determined by the topography of surrounding conditions, to be sure, but always forced to move on until its stock of energy is exhausted. If war demands the expenditure of this energy, it becomes destructive as a mountain torrent in time of freshet or cloud-burst; if peace supervenes, still this energy must find application, and in Egypt, after the close of the Alexandrian campaign, it fructified that intellectual domain as the Nile fertilized the valley which it traversed. Similarly, after the Greek and Roman civilization had been overwhelmed by the Goths and Vandals from the north and by the Saracens in the valley of the Nile, the Arabians diverted their talents into new and useful channels, and the flow of the stream of Saracen energies became subdued to the fructification of the whole of northern Africa and of Spain, and the development of pure and applied sciences among the Ptolemaic peoples was paralleled by that later observed among their conquerors. Destructive energy was replaced by constructive in all departments of human activity. Bagdad became a great cosmopolis in which, far more than in the metropolis of to-day, learning and scholarship and Aristotelian research were encouraged and honored. Haroun-al-Raschid instituted a school in every mosque in the whole Saracen empire, and his successor, Al-Mamum (A.D. 813–832), like the first Ptolemy, built up a great center of learning at Bagdad, collecting great libraries, calling to his court and to his colleges the men of the age, from all countries. His was the Augustan age of the Saracen empire.*

The Saracens boasted that they had produced more poets than all other nations combined; that they developed further than ever had been done before the scientific method now universal; that they substituted a study of nature, of phenomena and fact for speculation; that they promoted mathematics and the exact sciences in a previously unexampled manner; that, in their time, alchemists founded the science and the art of chemistry; that their learned men produced works on mechanics, solid and fluid, optics and astronomy, geometry and trigonometry, invented algebra and adopted the Indian numeration and figures. They invented all sorts of distilling, filtering, heating and fusing apparatus, instruments of precision for the astronomer, the chemist's balance and the simpler mechanical combinations. They even constructed tables of astronomical quantities, of specific gravities and other scientific reference compilations. The library at Cairo grew to enormous dimensions and is said to have included not less than 6,500 works on astronomy alone. This was a circulating library as well as of reference. The Spanish library of the khalifs is said to have numbered 600,000 volumes, its catalogue filling forty-four volumes. It is said that a physician was compelled to refuse the invitation of a sultan, to Bokhara, because the transportation of his library would have required 400 camels. Another physician, Honian, at Bagdad, maintained a regular business of translations from other languages and issued versions of Plato, of Aristotle and of other ancient learned authors. All then known fields of knowledge and of research were cultivated, an immense literature was developed and all this without let or hindrance, without the slightest censorship on the part of the monarch. All sorts of books of reference were produced, including an " Encyclopedic Dictionary of the Sciences " by Mohammed Abu Abdallah, and colleges dotted the whole extent of the empire. Colleges were then, as now, founded by wealthy men and provided with a permanent income by endowment.* One such college, at Bagdad, with an income of 15,000 dinars, taught 6,000 students of every class, rich and poor, noble and plebeian alike. Free scholarships were provided for the needy and ample salaries for the faculty. Of these learned teachers and investigators Al-Mamum asserted: " They are the elect of God, his best and most useful servants, whose lives are devoted to the improvement of their rational faculties; the teachers of wisdom who are the true luminaries and legislators of this world, which, without their aid, would again sink into ignorance and barbarism."

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* Draper.

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* Gibbon.

Professional schools were organized; that at Cairo setting the example of stringent entrance-requirements for all who would study medicine, long before the foundation of the European school at Salerno in Italy. In all directions, in the philosophies, in the sciences, in the arts, in all industries, this fund of stored energy of the Saracen race found useful expenditure. The resulting civilization was far more lofty and admirable than was that of Europe during those and for many succeeding centuries. In fact, it was only in the fifteenth century that sufficient liberty was enjoyed by European men of science to permit them to enter freely upon that now familiar field of intellectual occupation, and it was only at the beginning of the seventeenth century, in Europe, that any really notable progress began. Since then the acceleration of the movement has been like that of a falling stone.

Technical learning and the technical and professional schools of the Saracens came into Europe mainly by way of Spain, and the Moslem conquerors of that country made famous their centuries of rule by promoting the arts and sciences in all practical ways. By the tenth century, that country had become a center of learning from which streamed, throughout the continent, the rays of scientific research and the accumulated learning of all the then existing departments of science: The practical outcome was seen in well-built, paved and lighted cities, in heating, ventilating and elaborate furnishing, on a scale and in a manner that even our own time may admire and in some respects imitate. Especially admirable were their systems of social life, with freedom from the elsewhere universal dissipation of the time, with "feasts of reason and flow of soul" in place of banquets of savage character and flow of bowl. Learned men of all countries were ever-welcome guests and Andalusia became the resort of scholars and philosophers, and of men noted for their progress in scientific research, from all countries and all nations and of every race. All were equally welcome and all alike honored. When, in the fifteenth century, the Moors were driven out of the peninsula, the Castilians found a great civilization well established and the foundations of true learning well laid. The efforts of the anti-scientific parties of the time were never again able to entirely quench this great light; it grew steadily and pervaded not only all of Europe, but all the known world through its stimulation of research, its promotion of inventions and its application of all sciences and all arts in their thus improved state to the development of the best interests of the common people. In this vivification of the germs of our modern civilization, the Jews were particularly active and effective, and this was one of the most powerful influences leading to their later banishment. Their expulsion from Spain led to the distribution of the new civilization throughout the whole of continental Europe, wherever a Jew was admitted.

The Greeks thus carried the torch of scientific learning from their earliest days, its germ antecedent to Aristotle and Alexander by probably centuries, up to the Saracen conquest; the Arabian civilization carried it on into the fifteenth century, effectively cultivating a true philosophy of nature for at least eight hundred years; then came our own modern civilization as developed and evolved in France, Italy, Germany, Belgium, Spain and Great Britain. Its main progress has been observed during the last two or three centuries and its culmination, if culmination there be, has been observed during these last seventy-five years, since the establishment of existing systems of power-production, of transportation and of manufactures—and the inauguration of our recently developed systems of public schooling and higher scientific and technical education.

The study and investigation of mechanical science practically began in Europe with the work of that wonderfully versatile engineer, Leonardo da Vinci, whose biographies, written by men utterly ignorant of his greatest achievements, are devoted to accounts of his painting and sculpture, his verses and his travels and battles and sieges. Leonardo was the instigator of the sixteenth century renaissance of science and the technical arts and professions.* He was familiar with the Saracen literature and with their scientific work; their books and their learned men having come, by his time, into Italy and the south of France. He adopted research as the only guide in scientific matters, revived the Aristotelian and the Averroesian philosophical systems and applied these true methods to his work in applied mechanics, physics and all the natural sciences with which he, more than any other man of his day, probably, was familiar. His technical applications of the sciences were numerous and valuable and his familiarity with the literature and the science and with the learned men of his time gave currency to his productions that could not otherwise have been attained. He thus firmly founded the existing systems of thought and work in scientific and technical matters. All modern science and all contemporary workers in scientific and technical fields, whether of the schools or of the professions or in research, owe more to Leonardo than the average student can realize.

Finally came Newton and the great mathematicians, Lavoisier and the famous chemists, Boyle and the succeeding physicists, Watt and all the wonderful inventions of our century. By the end of the first quarter of this century the advancement due to all these developments was well under way and that world with which we are concerned took form.

Times have thus strangely changed in these later centuries. In the middle ages and earlier, when all the world was composed of few masters and many men, when the great body of mankind was ruled, and individuality was unknown among nations, even education was directed by the masters of men, and church and state were alike phases of aristocracy. The curriculum was prescribed by monastic rule, and the so-called "four learned professions" were theology ruled by the church, law constructed and manipulated for the monarch, medicine the refuge of younger sons of the rulers, and philosophy the resort of wealthy and aristocratic idlers. Engineering, the first and last and always essential basis of civilization and of all true advancement in material wealth, the necessary accompaniment of advancement in learning and the promoter of the most vital moral and spiritual elevation, was unrecognized by Greek, Roman and modern European alike, during the centuries preceding the nineteenth. Great mechanics and engineers were deified in the days of mythology, but they were ignored and contemned throughout historic times until our own saw the beginning of a real renaissance of the aristocracy of ideas, of true knowledge and of noblest powers of the mind of man. Individualism and the care of the state for the individual are the practical result of the progress of our own century. The Declaration of Independence and provision for the protection of the inventor are corner-stones in the foundation of the modern and current political creed, and the firm basis of this latest and only true development of the people. It is only when each elementary atom of a population is developed to its highest and best in knowledge, intelligence, independence and character that the great mass, the nation itself, becomes strongest and best. The specific gravity of its elementary molecule is that of the mightiest mass. Give the particles weight and value, and the mass assumes maximum value as a certain consequence. A hundred years ago the schools, the colleges and the universities of even Great Britain were inaccessible to the people of England; those of the continent of Europe were reserved, practically, to aristocracy: in the newly-organized United States of America, only, of all civilized countries, was education practically and legally free to all ranks and all classes. In these United States education was, from the first, recognized as the birthright of the people.

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* See particularly "Il codice Atlantico di Leonardo da Vinci." Milano. 1898.

In the Massachusetts Constitution of 1780 it was written: "The encouragement of the arts and sciences and of all literature tends to the honor of God, the advantage of the Christian religion and the benefit of this and the other United States of America." Wisdom and knowledge, as well as virtue, were recognized as essential to the prosperity of a nation, and the cultivation of the arts and sciences, as well as of literature, was made a duty of legislatures in order that the rights and liberties of the people should be conserved. The great Northwest Territory was controlled by a primary law, the famous ordinance of 1787, in which it was declared that "Schools and the means of education shall be forever encouraged, the perfection of the individual as the elementary atom of the State being the end sought." Later came the slow but still advancing recognition of the necessities of the individual in the perfection of the school system and of the various forms of curriculum required in each grade and in each class of educational institutions. While it seems sometimes questionable whether, with our combinations of masters and of men, of corporations and of trusts, of classes and of masses, the individual is not being again deprived of that liberty and opportunity which seemed on the point of being fully insured him, it is to be noted that, in all these kaleidoscopic movements of the modern world, the individual still retains his right and his power to rise from stratum to stratum, to pass from class to class, to rise or fall, or to swerve from old into new courses, just as readily and just as far as his desires and his natural powers impel and permit. "Liberty always and everywhere insists on the use of all legitimate materials at hand for the attainment of its purposes. Such materials are ability, education, foresight, invention, personal influence and material resources."* Only individual liberty to move in any and every direction in which one's talents, tendencies, interests, proclivities lead can give true progress to individual or to nation. Freedom to secure, not simply an education, but just the sort of education that one's talents and inclinations or one's necessities may seem to call for, is one of the most vitally important of those rights which Magna Charta and the Declaration of Independence have assured to mankind. The placing of schools of engineering beside those of law and of medicine, the rehabilitation of the profession as one of the learned, as perhaps the most learned of, professions, the general organization of courses of instruction in the arts and sciences—sciences applied as well as " pure "—and the extension of the school and college systems over the realms of technical, trade and professional instruction and training, have been the most obvious and fruitful results of the liberty of the individual and of the endeavors of our century to promote the interests of the citizen and through him the progress of the nation.

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* "Irresistible Tendencies." President Charles Kendall Adams. *Atlantic Monthly*, September, 1899, p. 293.

While it is perfectly true that the evolution of education, including those branches which we distinctively call technical, covers a period extending back to the beginning of civilization, if not of human life on this globe, it is none the less true that more has been accomplished during our own century, more during the period of seventy-five years in the history of which we have here and now such special interest, than during the centuries, millenniums, which preceded.

Three remarkable developments of the present century, all the outcome of great social processes of evolution in various departments of our later civilization, have compelled the attention of students of history and of sociology in these later days; illustrating the fact that all modern progress has been made by advances of continuously increasing importance. The rate of progression under the action of the mighty forces which have become so sensible, in these decades which have seen substantially all the grandest movements of humanity, like that of a stone falling under action of gravitation, has been in each of these directions an acceleration. These three most wonderful accelerations have been: (1) the progress of invention and of the mechanic arts; (2) the evolution of modern physical sciences; (3) the advancement of systematic methods of cultivation of the mind. Progress in the mechanic arts and engineering, scientific discovery, and the construction of the sciences, and that form of intellectual training which we call education have all constituted most important characteristics of the progress of the century.

At the beginning of this century the existing educational system had not taken form, and its most striking development, the education of a people for the life and work of a people, the supplementing of a purely—and most admirable and most desirable—gymnastic education by technical instruction and professional training in the industrial professions, had not become systematized. Especially is it the fact that the distinguishing characteristic of modern methods of education, classic and scientific, technical and professional alike—the placing of the work of instruction, in every branch of the pantology of modern educations, in the hands of specialists and of experts, of men fitted by special education, by peculiar experience, and by natural proclivities to communicate most of each special knowledge to the pupil—has only now, and even now not completely, come into the accepted platform and constitution of education. A generation ago, even, the proposition that, in education, as in all other departments of human activity, to insure success the work must be performed by the expert worker, was not admitted, and it was not unusual to place in charge of a department, or at the head of a college even, a man having no technical familiarity with the methods of the practitioner, whether mathematician or astronomer, chemist or physicist, engineer or classicist. Clergymen were given the place of the pedagogical expert; lawyers were made heads of schools of engineering; classicists were made presidents of schools of science; and the idea of finding a man fitted by practical experience and natural talent for the position only properly assigned to an expert professional was unrecognized in the general confusion attending the construction and operation of the educational system. To-day all this is changed. Clergymen control the schools of theology, lawyers take in hand the schools of law, and engineers are taking the management of the schools of engineering; and the latest and the least recognized forms of professional school are coming to be known as those exacting most of their students and adopting most extensive and intensive curricula.*

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* "Educational Problems. Electrical Engineering as a Profession." R.H. T. (Reprinted from the N. Y. Evening *Post*, September 10, 1898.)

A glance through the pages of history reveals the fundamental thought of the modern and so-called education in the spoken and written words of philosophers of all ages, and its practical embodiment in the school systems has been witnessed, in some degree, at least, from the earliest historic times. The first great university, that which even now stands, its time and surroundings being considered, as the representative university of all time, that founded by the Ptolemies over two thousand years ago, included technical learning and professional training in its curriculum, notwithstanding the anti-utilitarian sentiment of the Greek people and their philosophers and nobles. Astronomy and navigation, mechanics and engineering, mathematics and all then recognized applied sciences were there taught to all students and disciples by the most learned men of the time. The transfer of the arts and sciences and of all learning from Greece to Egypt, and by the Saracens to Spain, and from Spain and the shores of northern Africa to Europe, and through the centuries to our own times, has always been so effected as to maintain technical and professional schools as a part of the system of education of every state, and the organization of the schools at Bologna and at Salerno in connection with the medical and legal professions illustrated, centuries ago, the idea of the modern professional school. The Greek and the Roman and the Saracen and the modern European educations all alike were more than simply gymnastic and "classical;" all included more or less, in varying degree at different periods, the technical and practical side of education.

It was not, however, until the seventeenth century that special and precisely planned technical schools or departments of the university became recognized necessities in the minds of many men, and applied sciences were seen to be the real and ultimate end of the pursuit of the knowledge of the pure sciences, and the gymnastic forms of education to have an ulterior and vital purpose in the promotion of the welfare of the people. Plato had declared education to be the business of the state, and the inference was inevitable that the state should provide that education most likely to advantage the people. Milton pleaded for a "complete and perfect" education that should "fit a man to perform justly, skilfully and magnanimously all the offices, both private and public, of peace and war." Bacon had the same thought, and Comenius, his disciple, planned a real "university," to include in its faculty men of science learned in the applications of science in the arts as well as men learned in languages and literatures. The Marquis of Worcester, the inventor of one of the modern steam-engines, the exponent for his time of the truly broad and university-educated man, urged upon his monarch the organization of a system of technical schools for the purpose of promoting the highest interests of the nation; Descartes sought the same result in a similar manner in France, and, in that century, while all the sciences were taking new forms and making new and extraordinary progress through the then new systems of scientific research, the perfection and completing of the educational systems was a prominent thought in the minds of many of the greatest men of the day. Descartes, in fact, proposed a sort of Franklin Institute in which should be provided lectureships and schools for the people, a people's technical university—if that term, thus applied by John Scott Russell, may be admitted—in which the systematic and scientific development of all the educations likely to help the people to prepare themselves for the sequel of their lives should be effected. The foundation of the French "Conservatoire des Arts et Metiers," by the great inventor and mechanic, Vaucanson, was probably the first important actual embodiment of the ideas which had been familiar to Plato, to Aristotle, to the Ptolemies and their successors in the realm of education, in later times. Martin Luther was among these successors, and he and other great German educators early adopted the views of the leaders of thought of the preceding centuries. Germany was the first nation to put in practice the thesis of Plato and to inaugurate, formally and with considerable extent and symmetry, the systems of modern technical education of the people for the life and work of the people, and magnificently, as we may now perceive, has that nation profited by such wisdom and practical statecraft. To-day the German system of national education is the admiration of the world. It is now a half century since John Scott Russell made his first study of those schools of the people of which he wrote in 1869 so glowing a panegyric.* They have steadily improved and broadened their field from that day to this, and are still improving and maintaining their lead over other nations in many ways, although, if we may accept the judgment of some of their own ablest educators and professional men, our own country has, during the present generation, struck on in advance of them in some departments in methods and curricula. Trotzendorf, Sturm, Neander and Comenius, Spencer and Francke, Basedort and Pestalozzi and Hecker built foundations upon which arose a great system of useful and stimulating education of every class in the community, and in such manner as should give to all the power of making the most and best of every God-given faculty, physical, intellectual and spiritual. This system revivified and regenerated the German nation much as, in these later days, the "land-grant" legislation of our own country has inaugurated a new system and new views of the needs of the people and the duties of the state. It made evident the fact that, as Russell states the point, the education of the nation is to be divided into two distinct divisions, logically: the one, that which "educates and matures the man, and which we call 'general education;'" the other, that which "specially qualifies the citizen for fulfilling that narrow round of duties which the subdivisions of labor in civilized countries impose on the individual as his special contribution to the commonwealth and which we may call special or technical." In Germany, Russell found, as you or I may find to-day, the most systematic and economical and fruitful, the most "complete and perfect" national organization for the special care of this second division of educational work that the world has yet seen.

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* "Twenty years ago professional duty took me to Germany for the first time. I cannot forget my impression at the sight of whole nations growing up in the full enjoyment of systematic, organized, I might almost say perfect, education. I had already become acquainted with some theories and forms of education. I had read Plato's description of the perfect training for a nation. I was familiar with elementary school-teaching, and enjoyed the privileges of university education and the still higher education of the workshop. I was familiar with the system of Bell and Lancaster, having had personal acquaintance with its authors, and had myself taken an active part in schools of art and mechanics' institutions, but I confess to have been profoundly astonished—I may say humiliated—at the sight of nations whose rulers had chosen to undertake the systematic education of their people, and of peoples who had chosen to bear the burdens and to make the sacrifices necessary to obtain it. I do not know to what men or class of men in Germany the forethought, organization, and patriotism are to be attributed which made them lay aside personal ambition, political animosity, religious sectarianism, and state parsimony in order to unite all the classes of people in a unanimous effort to raise every rank in society to a higher condition of personal excellence and usefulness, and, by diffusing equality of education, to extinguish the most grievous of class distinctions."—"Systematic Technical Education;" John Scott Russell. London. 1869.

When, in our own country, we secure the union of this German national system of administration and this complete distribution of the statesman's care over all classes and in all localities, with our own peculiar and specially efficient system of union of the scientific with the practical, the combination of gymnastic teaching with scientific experimental methods of the laboratory, in all departments and in all technical and professional work, we shall have attained very nearly the ideal of Milton and of the great educators and the real statesmen of our own time. This must soon come. The course of modern progress in this department of national life has been practically one which has a history, as we have seen, dating back to the earliest days of Greek culture; but real progress, with acceleration of measurable degree, really began in the times of Milton and of Bacon, took on importance with the organization of the German national system of technical and professional education in connection with the older gymnastic systems, and assumed visible importance at about the time of the incorporation of the great enterprise whose accomplishments we here and now celebrate. During this century, and particularly since the last generation took a hand in the work, progress has been steady and increasingly rapid. Another generation should see our own country provided with an educational system, perfect and complete, broad as the continent, deep as modern life, and rich and fruitful as the best thought of the wisest educators and greatest statesmen can make it.

Every State and every nation owes to its people the organization of a general system of education—not abstract and ideal, not fitted to the purposes of the well-to-do citizens solely, not planned from the point of view of the older academician or fitted into the ancient monastic scheme—a system adapted to the immediate and practical needs of a great body of civilized people endeavoring to live and work and to enjoy the privileges of modern civilization, on an average income of between $600 and $700 a year for a family, in the settled portions of the country; when this is understood, the question finds easy solution—in words. The difficulties of securing the inauguration, in even our enlightened country, of such a system, in the face of long-standing prejudice, of existing and established curricula of the ancient and cloisteral type, of indifference on the part of politicians filling places belonging to statesmen, of ignorance, on the part not only of the average citizen and voter, but even on the part of the intelligent men of the country, very few of whom have given time to investigation, or thought to this most important of economical subjects, are beyond estimate. These difficulties, however, are certain to be in time overcome, for their removal is essential to the progress of our country in its great career.

The classification may, perhaps, take some such form as this:*

(*a*) A common-school system of general education providing the elementary studies of a good English education, perfecting the pupil in the arts of reading, writing and arithmetic, at least, and with so much of the most essential primary work in language, geography, etc., as space can be found for, without reducing the vitally important work to inefficiency. This system should be adapted to the needs of all classes.

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* This scheme was substantially constructed as here presented by the writer when, as member of the New Jersey Commission for Devising a Plan for Encouragement of Manufacturing Industries in that State and, as Secretary of the Commission, he prepared for the Commission such a scheme.

See Report of New Jersey State Commission, Trenton, 1878; also *Sibley Journal of Engineering*, June, 1892; "The Demands of the State;" also the *Trans. Am. Soc. M. E.*, 1892, Vol. XIV; and *Trans. Am. Soc. for Promotion of Engineering Education*, 1898; "Organization of Engineering Courses," etc.

(*b*) A system of special adaptation of primary instruction to the needs of children who must become skilled artisans and who cannot be kept in school by their parents longer than during the period of their growth to that size and age at which they can be made to assist in the support of the family. Such a system may, perhaps, prove to require special adaptation of text-books to the purpose, in which text-books the terms of the trades, and reading matter giving accounts of industrial processes, may be introduced.

(*c*) A system of trade-schools in which general and special instruction may be given pupils preparing to enter the leading industries, in which schools the principles underlying the principal vocations of the locality are to be taught and the essential actual manipulations of the trades are to be illustrated and taught by practical exercises until the pupil becomes expert.

Thus, the Germans have besprinkled all over their country schools of carpentry, blacksmithing, weaving, bleaching and dyeing, forestry, agriculture, etc.

These schools should be established in every city and town in the State.

(*d*) Polytechnic schools should be incorporated, formally and with system, into the great educational scheme of the State and of the country, in which higher work in the applied sciences and, usually, some trade or professional instruction should be offered students whose circumstances are such that they may be given an education extending toward the years of maturity and whose talents and inclinations lead them to select technical school work as introductory to their later practice of the industrial arts.

(*e*) Technical schools and colleges and professional schools within the colleges and universities, in which the highest professional instruction in the applied sciences and in the scientific basis of the profession may be offered those who are permitted by rare good fortune to secure a good, a liberal education while preparing for entrance into the professional school and upon their chosen line of life-work.

(*f*) Such a bureaucratic system of supervision and conduct, presumably by the State, acting through experts in all branches of educational work, and all imbued with the Miltonian idea, as will insure symmetry and efficiency of the whole great structure of education of the people for the life and work of the people.

(*g*) In the United States the work of the several States should, it would seem, be correlated by a great central, a national organization, a national university, presumably, to which all lines should converge straight from the most elementary of the primary departments and schools, through the whole system of academic and technical secondary schools and State colleges and universities, and which should thus serve at once as a source of authority and of instructing talent of the loftiest character; providing men of genius and giving grandest educational advantages to all the lower grades; raising up the level to which the tide of culture may rise in attaining the highest possible altitude, and serving, further, as the ultimate goal of the great minds of the nation.

(*h*) National bureaux of education having enlarged powers, wider duties and grander opportunities of engaging in the task of instituting and promoting systematic and general education, such as Milton would have approved, and serving as the great advisory and directing agents in the permanent task of maintaining and improving the symmetry and completeness of the whole national, State and local systems of general and special education.

Supplementing all these, and doing a work that cannot be performed by any system of public teaching in classes and schools, should be found in every city and town such institutions as this in Philadelphia, lending a hand to the ambitious and less fortunate members of the body politic who have been unable to secure the advantages of systematic instruction or who, having neglected opportunities of this sort in earlier life, later are awakened to the desirability of perfecting and completing an imperfect and incomplete education.

The grand developments in the direction of the education of the people for the life and work of the people, in these later times, have thus far been:

(1) The institution of the system of common school education in the United States, a system unequalled even now elsewhere, giving to every citizen a preparation for a life worth living, such as no people ever had before.

(2) The organization, first in France, of great technical schools under the supervision of the government, in which the older professional methods of training are adopted in the preparation of youth for the professions of the constructive arts and engineering.

(3) The establishment by Germany, in more complete form, of a system of national schools, manual training, trade and higher technical, such as is represented, in type, by the great Prussian school at Charlottenburg, near Berlin.

(4) The organization of special, isolated, usually privately endowed, polytechnic and engineering schools, like those of the United States and Great Britain, and which are typified by our military and naval academies, the Troy Polytechnic Institute, the Massachusetts Institute of Technology, the Stevens Institute of Technology and the Drexel Institute.

(5) The development of State universities devoted, in fair proportion, to the instruction of students in technical departments and schools under the patronage and care of the State, somewhat after the manner of the common schools—a system which finds its highest development in the Middle and Western States in this country, and which forms part of the whole educational system of the State. The existence of large and privately endowed colleges and universities in the Eastern States has prevented equal development on this side the Alleghenies.

" What is wanted in our day is that complete and perfect representative of one great and all-embracing system which shall, for its time, do what was done by the grandest of all ancient institutions, the greatest of all the ancient 'wonders of the world,' in its day—offer to all-comers opportunity to study and to pursue all the sciences, all the literatures and all the arts of the contemporary civilization. Ezra Cornell expressed the ideas of Plato and of Aristotle and of Milton and of John Scott Russell in a sentence: 'I would found an institution in which any person can find instruction in any study.'

"This Cornellian ambition, absurd as it may seem to the dull plodder in the ways of the mediæval educator and of the monastic regime, is precisely that of the German Empire and of its constituent political elements of the earlier generations, since the time of Luther.

"Once it is recognized as a great principle of politics and economics that the primary duty of the State—given a system of government which steadily maintains the law and preserves the peace—is to see that the people are taught to make themselves competent to make the most of life and of the marvellous opportunities which modern civilization presents to all men, the obvious universality of the scheme of public education and training 'for the sequel of the lives' of citizens is instantly recognized, and its practicability in a reasonable sense as well; for the powers of the State are to be invoked to their utmost limits."*

While common schools, as we know them, were organized in the older States during the colonial period, and in the newer States with the adoption of their constitutions and the formation of their State or even of their territorial governments, it was not until about 1825 that the condition of the country, industrially and politically, had become so well settled that the attention of the people could be given without distraction to the solution of the great problems involved in their thorough organization. Since then our present universal and remarkably efficient common school education has taken shape and has come to constitute the foundation of all secondary and higher education, liberal, classical, even technical and professional. To-day, the whole population of our country is at least educated in the common schools if not in the higher departments of our school and college system. This is the solid and enduring basis of the intellectual and social, and largely even of the moral, life of our nation.

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* "On the Organization of Engineering Courses, etc.:" "Trans. Am. Society for Promotion of Engineering Education," R. H. T.; 1898.

The organization of the great technical schools of Europe, the progenitors of our own technical and industrial schools, may perhaps be properly said to have begun with the inauguration, in 1785, of the French "Conservatoire Imperial des Arts et Métiers," as it is officially called. The establishment was, in 1793, placed in the hands of a "Commission temporaire des Arts," and, still later, the present title was conferred upon it by a decree of the "Convention Nationale." The "Commission temporaire" was fortunately able to preserve the splendid collections uninjured during the disturbed period of revolution in which they had charge of them, and even procured from the Convention a decree making their charge a "depot public" and authorizing the appointment of three "demonstrateurs" and a designer to conduct a course of instruction. A little later, the whole establishment was domiciled in the old priory of Saint-Martin-des-Champs. On its faculty-lists have been numbered many of the greatest names known to France and the world—Thenard, Charles, Darcet, Dupin, Clement, Berthollet, Gay Lussac, Arago, Pouillet, Poncelet, Ollivier, Bequerel, Moll, Alcorn, Tresca, Morin and Laussedat are names familiar throughout the civilized world.

The Conservatoire was not actually constituted a school of technical instruction, however, until 1819, and it has never been a school for the workingmen of France, but has been devoted to the education of students for the higher positions in the industrial system and to the training of professional engineers.

A more typical example of the form of industrial school which is most effective in the development of manufactures and the arts is the later "École Centrale des Arts et Manufactures," founded at Paris in 1829. This school was taken in charge by the government in 1858, and has since that time formed a part of that general system of industrial education to which France so largely owes her present position as a wealthy and prosperous nation. Students from all parts of France and from other countries as well are admitted. Although large numbers of the students are foreigners, this institution remains, as it was said by M. Morin and M. Tresca, "pour l'industrie, une des forces principales" of France.* Founded originally by an association of scientific men, which included MM. Dumas, Peclet, Olivier and others hardly less distinguished, it stood unaided nearly thirty years, and finally became one of the pillars of the state, and to-day furnishes a large proportion of the civil engineers of France.†

Other schools—as the École Polytechnique, l'École des Ponts et Chaussées at Paris, l'École des Mines at St. Étienne, and that at Alais, l'École des Arts et Métiers at Chalons, those at Aix and elsewhere, and the "Écoles Industrielles" at Mulhouse, Lyons, Lille and in other cities—aid in making the system of industrial education of France admirably perfect. These schools, with the exception of the "Écoles Industrielles," are under the direction of the state.

The trade schools are usually founded by municipal authority, and are under the direction of the city governments creating them. They fit young men to become good workmen and excellent superintendents. They are devoted peculiarly to instruction in the practical operations which constitute the trades. The "Polytechnique," which is, in a certain sense, the highest of the French technical schools, is largely, perhaps principally, a school of mathematics and of the pure allied sciences. L'École Centrale is the highest of the properly so-called industrial schools, and educates leading manufacturers and the directors of great industrial establishments.

The trade schools of Chalons, Aix and Angers were organized by a decree of December 30, 1865, for the instruction of all workers in wood and iron, and are only allowed to receive resident pupils, who are selected from among applicants for admission by a competitive examination. The German schools in which engineers or artisans are trained may be reduced to the following groups:

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* "De l'Organization de l'Enseignement industriel et de l'Enseignement professionel."

† Letter from General Morin to Mr. Jas. Forrest, Secretary of the British Institution of Civil Engineering.

(1) Polytechnic or technical high schools, in which the principles and practice of engineering are taught, sometimes with the aid of a workshop, but generally without it. The graduates aspire to be managing engineers of mines, railroads, manufacturing establishments, etc., each according to his special preparation.

(2) Intermediate technical schools, subdivided into (1) general technical schools, (2) weaving schools, (3) industrial art schools. The general technical schools may be classified into (*a*) higher elementary technical schools, (*b*) secondary technical schools, (*c*) building and mining schools. The graduates of these schools expect to become foremen in shops and works, with the possibility of attaining to a manager's position.

(3) Apprenticeship schools for the training of skilled workmen.

(4) Evening schools, available for artisans. These are attended by men who during the day follow their craft. The "Fortbildungsschulen," or continuation schools, belong in this category.

(5) Trade and professional schools for women.

This classification may be still further simplified in relation to mechanical engineers, foremen and artisans, and all schools devoted to their service will fall under one of the following heads: (1) polytechnic schools, with or without workshops; (2) secondary technical schools; (3) apprenticeship schools; (4) trade schools.

For admission, the polytechnics require sometimes more than the equivalent of an American college course, as the École Polytechnique; sometimes the equivalent of a full course at the Realschule, as at the German polytechnics; sometimes, the best that the preparatory schools can give, as at the Imperial Institute of Technology at St. Petersburg. The range and severity of the requirements for admission gradually diminish till, in the apprenticeship schools, only the rudiments of knowledge are demanded.

The "Gymnasia" in Germany are preparatory schools for the "Polytechnicum" as well as for the university; but the special preparatory schools for the former are usually the "Realschule."

In Europe, the custom has come to be almost universal to isolate the technical schools from the classical institutions and older universities. This has come about partly through the conviction that better work will be done by each class of college if allowed to work unhampered by the different methods and even the conflicting views, feelings, and traditions of the other, partly, perhaps, in consequence of their different foundations. Many able men favor each system, and the amalgamation of the university and the technical school is likely to be given faithful trial here and there on the continent, and in Great Britain perhaps still more completely; but they are to-day separately administered practically in nearly all cases. The view of the relative importance of manual and of gymnastic training of the mind which prevails generally in Europe is that, in the higher schools of technology at least, the training of the hands constitutes no part of the essential education of the engineer even, and that these schools should confine themselves entirely to the instruction of the student in the principles of his art, avoiding the practice, so far as it involves the use of the hands. It is perhaps a consequence of this belief and practice that the states of Europe have been, for years past, flooded with well-educated, untrained young aspirants for entrance into this vocation who not only have been unable to find employment, but who have, in many instances, been informed by employers that they are not wanted. It is the man who suitably unites theoretical and practical knowledge and training who is wanted and who best succeeds, in Germany no less than in the United States. The view held by so many of the higher schools of Germany and of France is that formerly inspiring the "École Polytechnique" at Paris, the first institution, working on the highest theoretical plane, produced in Europe.

Throughout Germany, technical schools and colleges, and trade schools are distributed so numerously that the visitor from the United States is not only impressed by the completeness of the system and by its universality, but is oppressed by the apprehension that his own country, unprovided with such efficient and essential means of giving to the people a good industrial education, and apparently having few citizens who understand the bearing of that fact upon the future prospects of the nation, as well as upon the character and attainments and upon the happiness and prosperity of the people, is likely to suffer severely when, in the near future, direct competition with this educated and trained nation of artisans shall produce those sad consequences against which history has over and over again warned us.

After their northern neighbors had inaugurated the new systems and methods of education, the Swiss commenced on a similar plan, and established a noble school at Zurich, where they placed some of the greatest instructors in Europe, and opened their "Polytechnicum" to the students from all parts of the world.* More than one-half the pupils are from other countries. The faculty consists of over a hundred professors, assistants and private teachers, and the number of students is above one thousand.

In Great Britain, the government and the people of that country have initiated trade schools and technical and industrial instruction in a few cities, and in connection with such institutions as King's College, the University, and the Crystal Palace Schools, in London; Owen's College, Manchester; Trinity College and others.

American schools, so far as developed in the United States, have been established, usually, by the several States, in compliance with an agreement entered into by them with the United States Government, under the terms of the Morrill Act, of 1862, the "Land Grant Bill."

Three-quarters of a century ago, the people of the United States entered upon one of those periods of renaissance in education which, at intervals of a few years, have marked the progress of educational work in this country, and "manual labor" schools were established in many places, in which the college course of education was accompanied by a course of manual labor, either with or without compensation. A "Manual Labor Academy" was opened in 1829 at Philadelphia, which was said to be remarkably successful, the students employing their hours of rest from study in various kinds of bodily work. "Every invalid resorting to this academy in the year 1830 was restored to health."

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* "Race Education." Sam'l Royce. New York, 1878.

A number of the States were provided with such schools by legislative action, and in several others, private enterprise did what the State governments had not done in this way. Among others, the Stockbridge Academy, in New Jersey, introduced this change into its program, and Gerrit Smith secured a similar arrangement for New York State at Peterboro.

A report to the House of Representatives of Pennsylvania, in 1832, indicated:

(1) That the expenses of education could thus be reduced one-half.

(2) That three hours' work per day had an important beneficial effect upon the health and strength and in promoting good spirits among students.

(3) That it had an equally useful effect upon the intellectual advancement of students.

(4) That such a system is advantageous in that it aids the impecunious student to obtain advantages in education which are ordinarily enjoyed by the rich only.

(5) That students thus trained make better citizens and more successful men than when not thus physically trained.

The Land Grant Colleges of the United States—of the several States, rather—are the product of one of the grandest examples of statesmanlike legislation that the world has yet seen—one second in importance and fruitfulness to no act of legislation subsequent to the promulgation of the Constitution of the United States. Like all great enterprises having for their purpose the benefit of the people by legislative enactment, this failed of complete success through the indifference, the folly, or the absolute stupidity of many of those public servants to whom its operation was entrusted; it has, nevertheless, produced incalculable good, both directly, in the foundation and partial support of technical education, and indirectly, and very probably to a vastly greater extent, through its influence upon the States, inducing them to take up and carry on the work from the point at which the General Government left it. It is largely to this legislation that the foundation of the now numerous State universities is due, and the organization of the systems of State education which now more or less completely cover the whole field from primary schools to universities in a large proportion of our States, illustrating the scheme of a complete system of State education to which reference was made, and of which the outline was given in the earlier part of this discussion, more satisfactorily than anywhere else outside of Germany.

The author of the Land Grant Bill, by which colleges of the useful arts were established in every State in the Union at the date of its passage, was Justin S. Morrill, then Senator from Vermont, who introduced the Bill in 1858, and secured its passage by a small majority, only to see it vetoed by James Buchanan, then President of the United States. But the statesmen who sought thus to perpetuate the strongest safeguard of the nation, the effective education of the people, lost none of their interest or enthusiasm, and persevered in their plan, bringing the Bill before the next Congress and the next, and finally they had the satisfaction of seeing this measure become a law during the administration of Lincoln and in the midst of the dark days of the war. "The genius of Lincoln rose to the occasion. With one hand he smote off the fetters of the slave; with the other he joined in a splendid effort to subjugate nature. On the second of July, 1862, while the announcement of emancipation was still on his desk, he signed the Act of Congress donating public lands for the establishment of colleges of agriculture and the mechanic arts."

In most cases the States complied fully with the terms of the Act—some of them more than completely. In the majority of the States the funds were invested in either State bonds or in a special bond made out for this particular purpose by the State and deposited in its treasury, and the returns were either the prescribed 5 per cent. or something more, in every case except that of the State of New York, which latter State never, until compelled by the courts, complied either in letter or in spirit with the law. Maine and Indiana paid 5 per cent.; New Hampshire, Vermont, Pennsylvania, North and South Carolina and Ohio paid 6, the funds being paid into their treasuries. Massachusetts was the only State in which the fund was divided, most of the State legislatures deciding at once and unhesitatingly that it would be better to hold the fund undivided and to either give it to some existing institution which should comply with the provisions of the grant, or founding an institution, as Cornell University, in the State of New York, in direct compliance with the terms of the law.

The following is a summary of the contributions made to the cause of "education of the people by the people for the people" from the earlier days of the Republic:*

(1) Lands by the township, under Acts of 1787 and 1800, amounting to over 1,000,000 acres, for the support of State universities.

(2) A considerable but unascertained proportion of the money surplus of $28,000,000 distributed to the States in 1836 and never recalled.

(3) A portion of the $3,500,000 constituting the share of education in the total proceeds of land-sales under the Percentage Acts of 1841 and later.

(4) A portion of the 3,500,000 acres accorded by different States to education out of the 9,500,000 acres given by Congress in 1841 for internal improvements.

(5) Further important sums not definitely known, from the sale of over 50,000,000 acres of swamp lands disposed of under provisions of the Act of 1850, from which source

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* Blackmar's Report, of 1890, to the Bureau of Education. Hoyt's Report, of 1892, to the Senate Committee on a National University. Thurston's "Technical Education in the United States," "Trans. A. S. M. E.," 1893.

alone the University of California is said to have derived important aid.

(6) Revenues in a number of States from the sale of saline lands, with appropriations thereof to the support of colleges of agriculture and the mechanic arts.

(7) The more than $15,000,000 already derived from the lands accorded to States by the Act of July 2, 1862, for the support of colleges and the mechanic arts; which grant has resulted not only in the establishment of many important technical institutions, but also at the same time in such strengthening of the State universities that some of them are thus early taking their places in the foreground of the great university field.

(8) The appropriation by Act of March 2, 1887, of $15,000 per annum to each State for experimental purposes in aid of scientific agriculture in the broadest sense of that term, a yet further incidental reinforcement of the many State universities.*

(9) The aggregate of over $20,000,000 appropriated for the support of the Military Academy at West Point and the Naval Academy at Annapolis.

(10) The establishment, equipment and support of the Naval Observatory and the purely scientific bureaus of the Government at Washington.

(11) The large sums of money appropriated for the convenience and support of the Congressional and departmental libraries.

(12) The hundreds of thousands expended in buildings for the scientific museums of the Government, and the more than $3,000,000 a year so wisely granted for their support.

Since the date of this report, the nation and various States have annually added hundreds of thousands of dollars to these great sums.

Of the now famous special schools, our U. S. Military

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* The State of New York, as stated in the message of the Governor, for 1892-93, taught in the public schools 1,073,093 children in the year 1892, and 772,426 were either educated in private schools or were not taught at all. The State expended in this work $21,134,516, which was $865,000 more than was paid out, on the same account, in 1891.

Academy was the first to take form, founded as it was in 1802; the Naval Academy was organized in 1845 and both have sustained a high reputation for the excellence of their curricula and the high scholarship of their graduates. The first of the independent schools privately endowed was the Rensselaer Polytechnic Institute, at Troy, N. Y., and its success led to the organization of many other schools of engineering in the succeeding generation. The Lawrence Scientific School was attached to Harvard University in 1847; the Department of Civil Engineering of the University of Michigan was organized in 1852; the Sheffield Scientific School was organized at Yale University in 1847, though much earlier proposed. The Massachusetts Institute of Technology was founded in 1864; Dartmouth College organized its technical departments in 1851 and the Thayer School in 1867. The Worcester Polytechnic Institute took form in 1868 and the Columbia College School of Mines in 1863. Peter Cooper founded the Cooper Institute in 1854 as a mixed educational and trade school and especially for the benefit of artisans and others unable to attend regularly the common and technical schools of regular curricula. The Stevens Institute of Technology (1871) organized as the first American school distinctively and especially devoted to the professional training of mechanical engineers and for the first time recognized that branch of engineering as a profession. The Towne Scientific School of the University of Pennsylvania and the technical departments of Cornell University were organized in 1868, and about 1885 the latter became recognized as colleges under the university organization. Since 1870, there have been almost annually organized and endowed schools of manual training, trade schools and polytechnic and professional engineering schools, until to-day every great city is provided with one or more. Philadelphia and Chicago are peculiarly fortunate in this respect. Nearly every large college or university has nominally, if not actually, professional and technical schools incorporated into its organization and the majority are doing admirable work in these directions. There are, to-day, about 100 reputable technical and engineering schools in the United States and they annually graduate about 1,000 students into the constructive professions.

The Franklin Institute of the State of Pennsylvania, in its work of promotion of the mechanic arts, has taken no small part in the development of these modern systems of evolution of the Miltonian idea. During the seventy-five years which have, to date, measured its period of useful life it has performed an enormous amount of helpful work in a variety of ways.* Its endeavors have always been effective in the union of science with practice; its membership has always included men of science and men of business, educators and philosophers and great mechanics; its work has always been carried on in fields of applied science with every apparatus of instruction, schools, lectures, systems of research, exhibitions of invention and construction, and all methods of promotion of technical training of young and old, learned and unlearned. The names of Ronaldson, Cresson, Rogers, the Merricks and the Sellers, of Bache and Morton and Wilson, Tatham, Heyl and Sartain, of Jones and Longstreth and Norris and Trautwine and Houston, and many others familiar to the world, have adorned a catalogue of officers and members such as perhaps can hardly be paralleled in any other State or in any other country.

The Institute has established and has carried on all these decades technical lectures, drawing schools, even a high school for a time; it has gathered together a very extensive, unique and valuable technical *free* library and has even published scientific and practical treatises, either officially or indirectly; it has printed, for now over seventy years, its *Journal of the Franklin Institute*, complete files of which have been probably more extensively and for a longer time maintained in the libraries and technical institutions of this country and of Europe than have been those of any other existing publication of its sort on either side the Atlantic.

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* For a detailed account of its work, see "A Sketch of its Organization and History," by Dr. Wm. H. Wahl, Secretary of the Institute; published by the Institute, 1895.

It has even longer maintained a " Committee on Science and the Arts," empowered to examine and report on inventions and advances in the mechanic arts and applied sciences. The files of the *Journal* are rich in contributions of useful and extensively important matter from this committee. Medals and premiums have been offered and awarded for great inventions and improvements in the arts and in mechanisms, and the careful investigation of claims and the selection of worthy objects of such honors by the representatives of the Institute has been of immense assistance in the promotion of the highest material interests of our country. These gratuitous services have never been and can never be adequately appreciated or recognized. These committees and the *Journal* have always been under careful surveillance by the best men of city and State. The editorship of the *Journal* has illustrated this fact, for its list contains the names of Dr. Thos. P. Jones, Alexander Dallas Bache, C. B. Trego, Profs. John F. Frazer, Henry Morton and Geo. F. Barker, Robert Briggs, and two periods of service are assigned to Dr. Wm. H. Wahl, the present Secretary and editor. The Committee on Publication, always supervising the work with conscientious care, has consisted, also, of the best men in the membership of the Institute. It may well be doubted if any journal in the world has a richer list of technical contributions.

The great exhibition of American manufactures of 1824 and its successors have had an immense influence in the improvement of all the arts and manufactures of our country. In that of 1874 more than 200 silver and over 220 bronze medals and 650 diplomas were awarded to as many deserving products of American invention and skill. The electrical exhibition of 1884 probably did more to show what were the prospects of the then infant industry than any other incident or influence of the time. It was the first of its kind, and gave a prodigious impetus to that vocation and those many industries which are to-day grouped within the special field of electrical engineering. The greatest men of science, the most famous mechanics and the ablest manufacturers of mechanism found there attractions and impressive novelties that had hitherto been to them almost undreamed of. A National Conference of Electricians, then necessarily mainly composed of physicists—for this branch of mechanical engineering had not then taken form as a department of construction or a division of the profession of engineering—was organized, and the officers of the exhibition and this congress, together, laid the foundations of the vast structure now constituting such an imposing division of our industrial system.

Researches like those described in the report of the committee organized to investigate the theory and practice of hydraulic motor construction, in the report on steam-boiler explosions, still an engineer's classic, and in that of the committee investigating the strength of the materials of construction, were at once useful and impressive. A Weather Bureau, even, was organized in 1843, and the later State weather-service and that of the United States may be fairly claimed to have grown out of that first work of this kind. The now universal system of standard screw-threads was the product of the studies of another committee, and the later investigations of water-supply for the city of Philadelphia, of the efficiencies of dynamo-electric machines and of the duration and efficiency of electric lamps, have continued the early-established practice of the Institute into our own time.

All this enormous amount of work in the promotion of the useful arts and applied sciences has been the voluntary service of able men, and not a dollar has been expended for their precious and invaluable time and thought and labor. It may well be doubted whether the history of any country or of any institution gives nobler exemplification of true patriotism.

The work of this now famous institution has not been simply, however, in the departments which have been mentioned; it has done a great work in aiding other enterprises. For a century and more this country, following the lead of its great statesmen of the days of the Revolution and of the early period of our existence as a nation, adopting the principles so admirably expressed by Hamilton and sustained by Washington, Jefferson and all their immediate successors, has made the promotion of the industrial arts a primary business in legislation and through executive action. This policy has borne fruit in the institution of a remarkably effective system of patent-law, in the organization of all the essential manufacturing industries and in the advancement of agriculture, directly and indirectly; supplying a home market for its products and giving it machinery which harvests its grain at ten times the rate usual seventy-five years ago, which transports it a thousand miles at less cost to the owner than then for a day's journey to market, and which opens the most distant lands of the trans-Mississippi region to settlement by the sons of the original thirteen States. In this work the Franklin Institute has taken part, and in no manner more effectively than in the inauguration of exhibitions of the products of industry, in the assistance in many ways of the managers of the great International Exhibition of 1876, and the promotion, jointly with the Philadelphia Commercial Museum, of the admirable Philadelphia Exposition of 1899.

The outcome of the policy of Hamilton has been the successful construction of a great system of domestic industries which, now that it has reached its period of maturity, is not only capable of supplying to our own people the cheapest products, the best products and the most abundant, but is also at the same time making compensation to its working people in the highest wages paid in the world, giving them the means of buying more of the comforts and the luxuries of modern life than any other people, while extending the market for the product of each industry and of each producer by making it possible for the members of every craft, and for every individual earning wages, to buy of every other producer. The fact that it is mainly by the payment of high wages to the wage-earner that a market can be made for every product at best advantage has never before in the history of the world been so well illustrated. In this great work of promotion of the whole system of American industries, Pennsylvania, and especially Philadelphia, and particularly the Franklin Institute, has had efficient part, and the possibility of that novelty—most astounding to the disciples of Cobden and to the practitioners of the Hamiltonian method as well—has arisen from this most successful and well-sustained work of the nineteenth century in our country. An "Export Exposition" in the United States, at the end of a century of, on the whole, steady and consistent support of the policy of upbuilding and maintenance of home industries, is a lesson to the world and one which economists of the ancient sort may well study with profit. Free institutions, the patent system, the protection of domestic trade and manufactures, the consequent growth of the industrial arts, and of manufactures, the resultant provision of a market for the agriculturist, the marvellous stimulation of invention, the growth of a people in intelligence, ambition, productivity and prosperity, which have all come of the enlightened policy of the founders of the nation, are admirably illustrated at this great exposition, the crowning glory of the Franklin Institute and of the merchants of Philadelphia, and may well astonish the world.

Thus the "Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts" continues, after seventy-five years of good work, to do its noble duty more effectively each year. May the work so well begun in our century continue with increasing efficiency for centuries still to come!

THE MODERN WARSHIP,

AS COMBINING IN ITSELF THE HIGHEST RESULTS OF SKILL, INGENUITY AND SCIENTIFIC KNOWLEDGE.

By REAR-ADMIRAL GEORGE W. MELVILLE,
Engineer-in-Chief, U. S. Navy.

GEORGE W. MELVILLE.

Before proceeding to discuss the subject which has been assigned me, I desire to express the great pleasure I feel in being with you on this important occasion, celebrating as it does the foundation of an institution which has done so much for the advancement of engineering and the mechanic arts. As one whose whole life from boyhood has been spent in connection with one of the branches of engineering, I feel an especial pleasure at being permitted to assist in this celebration. I want also to express my high appreciation of the honor which has been paid me in asking me to be one of the speakers. I do so with added pleasure from the fact that a great deal of the work with which I have been specially associated has been constructed here in your own city, and by men much of whose training in many cases has been due to the Franklin Institute.

The subject which has been assigned me is one of the greatest interest to an engineer, for the modern warship is the complete fruition and triumph of so many branches of the great science of engineering. Although in the ultimate analysis we owe everything to nature, we may well say that in the old wooden ships propelled by sails a very large proportion was due almost directly to nature, with only a minor part played by the artisan and the engineer; while in the modern ship, nature's part is strictly confined to the crudest of raw materials, and the finished product represents, as the title of my remarks so well expresses, the highest development of skill, ingenuity and science in engineering and the mechanic arts.

Under the circumstances of this discussion, we may be pardoned if, in a retrospective consideration of the subject, we limit our review to steam vessels, for the reason, as I have already remarked, that the part of the engineer (using that term in its broad sense) in the old sailing vessels was exceedingly limited. We shall, by contrast, be enabled to appreciate more fully the wonderful entity which we call the modern warship, if we consider the first one.

It will interest you all very much, I am sure, to know that the first steam war vessel in the world was built for our navy, and was designed by Robert Fulton, who first made steam navigation at all practicable; and the construction of this vessel antedated the founding of this Institute only about ten years. This first vessel was called the "Demologos," or "Fulton the First," and while of what would now be considered very small dimensions, was, nevertheless, a wonder of the period. She was 156 feet long, 56 feet beam and 20 feet deep, measuring 2,475 tons, having a single water-wheel in a central well, and capable of steaming about six knots. The battery comprised twenty guns of the largest size at that date, a number of them having been taken from a captured British vessel. The hull, of course, was of wood, and the boilers were of copper. She was not completed until just after the termination of the War of 1812, so that she never saw any active service, and was blown up by an explosion of her magazine in 1829.

The next steam war vessel, also called the "Fulton," and completed in 1837, was somewhat longer than the first "Fulton," but with less beam, and proved a very successful ship for the period, being capable of steaming twelve knots per hour under favorable conditions. A most interesting thing in connection with this old vessel is the fact that the engineer who designed her machinery and superintended its erection became her chief engineer when she was commissioned, and thereby became the first engineer in the United States Navy. This distinguished gentleman is still alive and in the active practice of his profession. Doubtless many of you will at once know that I can only refer to Mr. Charles H. Haswell, known to every mechanic in the United States as the author of "Haswell's Pocketbook." I think we may all take great pleasure in the thought that this venerable and distinguished gentleman, who is not only the Nestor of our profession, but one of its chief ornaments, has been spared to see the growth of the war vessel from the original "Demologos" to our "Oregon" and "Minneapolis," and the merchant steamer, from the original "Clermont" to the "St. Louis" and the "Campania."

After the building of the "Fulton," steam vessels were added to the navy at regular intervals, each class marking an improvement on the preceding ones, until shortly before the commencement of our Civil War we had a class of fine frigates, which in ordnance, machinery and hull were justly considered the finest in the world.

The necessities of the Civil War, of course, gave a tremendous impetus to naval construction, and at this period we have the beginning of the evolution of the modern war vessel. In engineering, as applied to machinery and hulls, several names stand out preëminent at this period, and as strictly germane to my theme I may mention the work of two of them. The Engineer-in-Chief of the Navy during this period was Commodore Benjamin F. Isherwood, an engineer whose practical skill, ability as a designer and high scientific attainments have never been surpassed. One of the problems which he had to solve was the construction of machinery which should be thoroughly trustworthy in the hands of men of very limited experience. This led him, contrary to what would ordinarily be considered good designing, but which, under the circumstances, in my opinion, was consummate engineering skill, to build machinery very heavy, but which, as a matter of fact, never broke down and which carried our guns to victory. In those days, just as in our own, the "man behind the gun" may be most in evidence, but without the "man behind the shovel" he would never have been able to get within range of the enemy.

The destructive career of the "Alabama" had led our authorities to decide upon the construction of a class of vessels which should be faster than any others afloat, in order that these commerce destroyers might be hunted down and themselves meet the fate which they had so often dealt out to others. Here, again, Isherwood's consummate skill and mastery of his profession showed itself. The material of the hulls was still wood, which gave a platform for the machinery altogether too flexible to permit of the type of engines which we now use; consequently he designed what were known as geared engines, which he, better than any one else, knew were extremely heavy, but the great point is that they enabled him to accomplish exactly what he set out to do. The "Wampanoag," the first of these vessels, in 1868 made the unprecedented record of nearly seventeen knots for thirty-six hours in a rough sea, and for several periods of six hours, seventeen and one-half knots. At that time no other vessel in the world, either war or merchant steamer, approached this speed within three knots.

About this time Mr. Isherwood conducted a number of experiments in connection with the expansion of steam, and boldly enunciated principles which the rest of the engineering world in many cases denounced as erroneous, but which are now accepted as fundamental facts in thermodynamics. This is notably the case with respect to cylinder condensation, as to which he was the first to enunciate the true principle.

Another great engineer became famous at this time, although he had been doing splendid work and helping to develop the war vessel before, namely, Captain John Ericsson. You all know the story of the first monitor, and it is not necessary for me to repeat it. I only wish to remark as apropos of my theme that here was a vessel which in hull, machinery and ordnance was the work of engineers, and which for that period represented the highest embodiment of engineering skill and talent. It is worth noting in this connection that the success of the "Monitor" in her engagement with the "Merrimac" was due almost entirely to the skill of her engineers, Stimers and Newton. They were thoroughly familiar with every detail of her machinery, which needed skill to keep it in good order, and, as is well known, after the accident to the gallant commander, Worden, Stimers fought the guns while Lieutenant Greene, the executive officer, took command in the conning tower.

I must not neglect to state that splendid work during this period was done for our ordnance; and the development of this branch of engineering, largely due to the skill and ingenuity of Admiral Dahlgren, was such that at the end of the Civil War our naval guns were recognized as the best in the world.

There now comes a period in our naval history which, as far as actual results are concerned, may just as well be passed over, for while our designers were keeping abreast of the times, we were not building anything new in either ships, guns or machinery. Beginning with 1883, however, a new era dawned for the navy and we began the building of our White Squadron, which has so appropriately been termed the "New Navy," and in connection with these new ships I shall endeavor to go into some details which will thoroughly prove the correctness of the theme which has been given me to discuss.

What is the problem that confronts the naval designer? The maximum of offense, combined also with the maximum of defense, and with a maximum of mobility. It is important to note the limitation upon the naval designer as regards one vital element, namely, weight, for this has far-reaching effects in every feature of design, and differentiates in a most marked way his work from that of a designer of somewhat similar works for use on shore.

While it has been aptly said that the war vessel is a "gun platform," and it would therefore almost seem that everything else must be subordinated to securing a maximum gun fire, the vessel must be prepared to withstand an attack of an opponent of equal force, which necessitates close attention to the defensive elements. Now, under the very best circumstances, the weight of the bare hull will approach 50 per cent. of the entire displacement, which, as you know, simply means the weight of the completed ship with everything on board, so that we have left only somewhat more than half of the displacement for guns, armor, ammunition, machinery, coal and stores. The first problem then is to construct a hull which shall safely carry all the weights, and do so with a minimum amount of material. This is a problem where the skill and ingenuity of the static engineer, for such the naval architect really is, has great room for exercise, and we see it carried out in the disposition of material in shapes which both theory and practice have shown to give the greatest strength for least weight. We see it also in the careful arrangement of frames, keelsons, longitudinal and transverse bulkheads, plating and deck stringers, while the protective deck (popularly supposed to be only for keeping out projectiles) also becomes in the hands of a skilful designer an important element of strength.

The ship must also be unsinkable, or at least as nearly so as possible, and this has led to the subdivision into water-tight compartments, and great ingenuity has been displayed in devising schemes for water-tight doors, which are absolutely necessary to give access from one compartment to another, but which, unless very carefully designed and constructed, may in time of need be a source of danger instead of safety. The latest developments in protection against submersion have taken the form of a belt of cellulose, a material which, when perforated by shot and exposed to water, immediately swells up and excludes a further inrush of water.

Great skill and ingenuity must also be displayed in the proper adjustment of weights to secure correct trim, and this, in connection with the form of the ship, must be such as to give ample stability, combined with steadiness of gun platform. This is an instance where the modern war vessel is a vast improvement on those of years ago, when the question whether a ship would be an easy or a hard roller was almost entirely a matter of luck. Now it is a matter of calculation and design, and the skilful naval architect is able to guarantee a vessel which will withstand any storm, be comfortable as regards motion, and provide a steady platform for the guns.

We may also note in this connection that the modern vessel is a striking example of what ingenuity and skill can do to make habitable and comfortable, compartments that are at best meager and crowded. We ordinarily consider light, water and air as synonymous with what is free and obtainable without effort, yet on the modern war vessel all these elements are due to the skill of the engineer. In place of the tallow candle of our forefathers, we have the electric light; in place of the casks of water many days old and far from palatable, we have absolutely pure and sparkling distilled water—this distilled water has contributed enormously to the excellent health of our crews, as was brought to the public attention in a most marked way during our recent war with Spain, when the crews of our naval vessels had hardly a man on the sick list, while the armies had enormous numbers ineffective. With its numerous bulkheads dividing it into small compartments, the modern war vessel can have no natural circulation of air, and the engineer provides pure air by artificial means. Steam radiators also make both officers and men comfortable in any kind of weather.

As a final item in connection with this branch of the subject, we may mention the remarkable development of scientific knowledge, ingenuity and skill in the prediction and determination of powers and speeds for large vessels from experiments on small wax models. Here we have combined the work of the mathematician and the physicist in working out the laws and formula involved, and the skill of the engineer and mechanician in the design and manipulation of the apparatus.

Turning now to the question of guns and armor, we have a most marked illustration of the accuracy of our theme. At the close of the Civil War our guns were still principally cast-iron smooth-bores. Progress has changed all this into the modern high-powered steel breech-loading rifle, weighing many tons, and driving at immense velocity a projectile whose encounter with an obstacle may be truly likened to that of one of Jove's thunderbolts. The stress coming upon the metal in one of these guns is as great as can possibly be allowed with safety, and the demands for greater powers have called for all the skill of the metallurgist, combined with the ingenuity and talent of the engineer, in so disposing the metal as to get maximum results with minimum weights. The latest development in these guns, consisting of what is known as the "wire-wound gun," is extremely interesting, as showing how a form of construction, which, at first sight, might seem anything but the best, is nevertheless the disposition of the material which theory shows is most desirable, and practice thoroughly confirms.

It will, doubtless, interest you to hear a few figures of the performance of some of these great guns. The latest authorities state that a 12·5-inch breech-loading rifle, 50 calibers long, and weighing 83 tons, will propel a shell weighing 880 pounds, by a powder charge of 624 pounds, at a velocity of over 2,620 feet per second, giving an energy at the muzzle of over 40,000 foot-tons, capable of penetrating at the muzzle over 45 inches of iron. This energy means that one of our battleships of about 12,000 tons displacement, and which could carry four of these guns, would at a single discharge develop a power sufficient to lift her bodily nearly 15 feet. It can readily be imagined, therefore, what the effect of a projectile from one of these guns would be when striking another vessel at close range.

It is an extremely interesting story to read of what has been appropriately styled the "duel between guns and armor." As fast as one is improved so that its victory over the other seems assured, some inventor comes to the front with an improvement in the latter, which for a time puts it ahead. The armor on our monitors during the Civil War consisted simply of a number of 1-inch plates bolted together. At the present day, a modern projectile would go through such armor as easily as a bullet penetrates pine boards, but long ago it was discovered that a given thickness of armor was much more efficient if rolled in a solid plate, and this was developed until some of the older English battleships had iron armor as thick as 24 inches. The development of the gun soon showed that it was impossible to keep pace with it by mere additions to the thickness of the simple armor, for a point was quickly reached where it was impossible to carry the necessary weight of armor that would be thick enough. Then came the use of special plates, the compound armor, where a hard face to break up the projectile was welded to a softer back to give the necessary strength. This was followed by steel armor, and then by the well-known Harvey process, which resembled the compound armor in having a hard face with a softer back, but where the plates were made from a single ingot without any welding. The Harvey process enabled an enormously greater resistance to be obtained with a given weight of armor, but even it has been surpassed by the Krupp process, which enables 12 inches thickness to give the same resistance as 15 of Harveyized plates.

In connection with armor plates great skill and ingenuity has been necessary to provide for giving them the proper shape and for enabling necessary machine work to be done on them after they are in position, inasmuch as the hardening process makes it practically impossible to do any work on the face of the finished plates with ordinary tools. Here an application of electricity for giving a local annealing where it was necessary to work with tools enabled the solution of this problem.

The work of the artillerist is not confined to the design and manufacture of the guns and armor alone, but the gun carriages are also important features of his work, and here there has been a great display of skill and ingenuity in devising means for the ready manipulation of these ponderous masses, and the control of the recoil due to the enormous development of energy when the gun is discharged. This is true both of the manipulation by hand and the control of the turntables, or turrets, for the larger guns, and the ease with which a turret and its contained guns, weighing several hundred tons, can be controlled by the movement of a single lever so that the pointing of the gun is almost as simple as that of an ordinary musket, is really surprising.

The chemist also has had an important part to play in connection with ordnance work, in the development of powders which would enable the enormous energy necessary to be developed with safety to the structure of the gun. With the powder used during our Civil War it would be impossible to get the results of to-day. The development has been through what were known as slow-burning powders down to the smokeless powder of the present, where the saltpetre and charcoal of our ancestors have been displaced by the combination resulting from the treatment of cotton with nitric acid. The difference in the energy of the ordinary slow-burning powder and of the smokeless powder now used can be seen by consulting any table where the two are compared. One which I recently examined showed that guns, otherwise practically identical, required with the same weight of projectile three times the weight of ordinary powder to get the same velocity as with smokeless powder.

We must not forget, while discussing ordnance, the remarkable development of what are known as "quick-firing guns." This, as you know, is really the adaptation to large guns of the kind of ammunition and breech mechanism used on the modern small arms, and it has been carried so far that quick-firing guns are now made of as large caliber as 8-inch, giving a muzzle energy of over 10,000 foot-tons, while the number of times the gun can be discharged in a given interval is about double that of the ordinary breech loader. In the smaller sizes of these quick-firing guns the rapidity of fire is almost incredible, and I remember being particularly struck by the results of repeated trials, showing that it was possible from a six-pounder to have five projectiles in the air at once.

More than a quarter of a century ago what are known as machine guns were introduced; that is, weapons of small caliber approximating to that of ordinary small arms and slightly larger, were so arranged that the ammunition could be fed almost continuously and the rapidity of fire be so great that a single weapon would be equal to a company of soldiers. As you are doubtless aware, the Gatling gun was the earliest of these. These, too, have been developed during the intervening years, until it would seem that finality has almost been reached in the Maxim gun, where, when once started, it continues to discharge itself by the effect of its own recoil, until the old figure of "iron rain and leaden hail" becomes a simple matter of fact. The Maxim gun will fire 600 shots per minute from a caliber of 0·45 inch or less.

We come now to the machinery of the modern vessel, and I trust that you will pardon me if I go into greater detail here, because this is my own special field and one in which it has been my lot to have been intimately associated with the construction of our new fleet. Here, more than almost anywhere else in the war vessel, the constant demand has been for greater power on less weight, and at the same time the demand has also been for thoroughly reliable machinery that would also be economical.

Progress has been so rapid that it sometimes seems that we hardly have time to get out a design as nearly perfect as possible and see it thoroughly tested in service before improvements have been suggested that render what appeared so perfect relatively obsolete.

Shortly before I became Engineer-in-Chief of the Navy, forced draught had been re-introduced, after many years of disuse. This at once gave an enormous increase of boiler power with a very slight increase of weight, due to the burning of a much larger amount of coal on a given grate surface. The shell boiler was developed until its design seemed nearly perfect, but we were confronted with the problem of getting plates sufficiently thick to withstand the increasing steam pressures in the large boilers and still be able to properly work the plates in our shops. The weight of these boilers was always very great for the power developed, and in the large sizes which they had reached, the utmost skill was necessary for their proper care and maintenance. Shortly before the time had come when further progress with the shell boiler seemed impossible, the water-tube boiler was developed to such a point that it gave us the necessary solution of the problem, and it now seems quite certain that, for some time to come at least, the boiler problem has resolved itself into a determination of the best form of water-tube boiler, inasmuch as we are sure we can construct boilers which will withstand any pressures that are likely to be used and which are satisfactory in every other respect. These boilers offer almost absolute safety against disastrous explosion, afford a great reduction in weight, and are built to withstand comparatively rough treatment as far as heat is concerned, thus giving freedom from such troubles as leaky tubes and leaky seams, to which large shell boilers were very liable.

The demand for reduction of weights in the engines has been met by the use of stronger materials, and also their disposition in shapes where a given weight of material offers the greatest resistance. We thus have steel castings to replace cast iron; hollow forgings of oil-tempered steel, and the use of bronzes of double the strength of the older compositions. Besides the greater strength of the materials, just as important an item is their much greater reliability. Our manufacturers to-day can furnish us with forgings as to which we know that the results obtained on test pieces will be absolutely true of every part of the whole mass.

Weights have also been greatly reduced by using engines which run at much greater speeds than formerly obtained. This seems a sufficiently simple matter, and yet it was not possible until the improvement came in materials, combined with an accurate scientific knowledge of some of the questions confronting the marine engineer, which had formerly been solved almost by rule of thumb. This is notably the case with propeller design, for it was the mistaken notions on this point that really held down the engine speeds. Inasmuch as the whole office of the motive machinery is to turn the propellers, it might seem that it would be necessary to design the propeller first and make everything else to suit it; but fortunately, now that we have accurate scientific knowledge of the conditions governing propeller design, we know that the propeller can be arranged to suit almost any speeds found desirable for the engines, and this enables us to choose engine speeds which will give us both lighter and more economical ones than were possible in olden days.

A problem in the design of engines for war vessels, which is of considerable difficulty, and the solution of which is not yet thoroughly satisfactory, is that of securing economical results at ordinary cruising speeds, with the capacity for the power necessary at maximum speeds. As you are doubtless aware, the power necessary to drive a vessel varies approximately as the cube of the speed, so that if, as is ordinarily the case, the cruising speed is about half the maximum, the power to be developed is one-eighth or less of the maximum. As was very cleverly expressed by one of my former assistants (Professor Hollis) some years ago, the problem is like that of having a beast of burden whose maximum power will be that of an elephant, but whose appetite is so adjustable that he could be economically used for work which could be performed by a donkey. You well know that an elephant would eat about the same whatever work he was doing, and while this is not exactly true of a steam engine, it nevertheless is true that its economy, when worked at powers which are so small a percentage of the maximum, is very much reduced. In some of our ships we have tried to solve this by arranging two sets of engines on each shaft, so that at the moderate powers the forward set can be uncoupled. The ill-fated "Maine" had an arrangement whereby the large cylinders of her triple expansion engines could be disconnected, leaving the engines to run as smaller compounds at cruising speeds. A somewhat similar arrangement is in use on the "Nashville," where the large cylinder of a quadruple expansion engine can be thrown out, leaving a triple expansion for lower powers. The objection to all of these is that, if it becomes necessary in an emergency to get full power, it is often impossible to stop to couple up. This was exemplified in a marked way in the case of the "Brooklyn" during the fight at Santiago. She was cruising with her after engines only when Cervera's fleet came out, and it was felt that there was not time to stop to couple up, which would have necessitated from twenty minutes to half an hour. The distribution of the power among more than two shafts offers another solution, which was used on the "Columbia" and "Minneapolis." Personally, I believe that this system, if properly carried out, would be entirely satisfactory, but it would involve the use of the center screw only for ordinary cruising, and a ship, as you doubtless know, is not so handy with one screw as with two. Our latest design to meet the desire to use two screws and still get relatively small engines for cruising speeds is to use three screws but make the engine driving the center one half the total power, leaving each of the wing screws to develop only a quarter of the full power. We have not as yet built any vessels on this plan, so that, while theoretically we have every reason to anticipate entire success, it has not as yet been tried in practice.

A very interesting illustration of the application of ingenuity and scientific knowledge is the method adopted for balancing the engines so as to avoid vibration of the hull. As engine speeds and hull dimensions increased, there came a combination of circumstances causing excessive vibration of the hull due to unbalanced inertia stresses of the reciprocating parts of the engines. The solution is a very simple adaptation of a type of engine desirable for other reasons with a special arrangement of crank angles and weights of reciprocating parts. The adoption of the steam turbine has also been suggested to accomplish this same object, and turbines have been employed on some torpedo boats. With certain very promising features, there are, however, some great disadvantages, and before the steam turbine becomes a formidable rival of the ordinary type of engine an enormous amount of skill and ingenuity must be exercised, and the lines along which they can act are not yet apparent.

I have already referred to the three vital elements in warship design as offense, defense and mobility, and the best combinations of these features to secure maximum results tax the judgment and experience of the designer, as well as his skill and ingenuity. If time permitted, it would be of the greatest interest to show how the necessity of maximum results in particular items has given us special classes of vessels. Thus in the battleship, which must give and take heavy blows, mobility or speed has been sacrificed, while in the armored cruiser both guns and armor have been reduced to secure high speed. In the torpedo boat, speed is absolutely vital and everything else is sacrificed to it. The tendency just now seems to be along the line of having only one class of armored vessels which will be very powerful armored cruisers with good armor protection and high speed. This means a vessel of about 12,000 to 14,000 tons displacement, with 8 to 10 inches of Krupp armor, a battery of 10-inch rapid-fire guns, and a speed of about twenty to twenty-one knots.

We have now given a hasty glance at the principal elements of the modern war vessel, although I regret that the limited time at my command has forbidden the consideration of many features which could not have failed to be of interest to you, such as the workshops on board where the necessary routine repairs are made to keep the great machine in working order; the electric installation for lighting the various portions of the ship and providing the searchlights; the elaborate drainage system with the necessary pumps; and the torpedoes, with their wonderfully intricate and delicate machinery, which is so arranged as to work automatically after being discharged from the ship, in a way that would seem to indicate human control at every moment. I trust, however, that you will have heard enough to satisfy you that the theme of my remarks is fully borne out by the facts which have been adduced.

The truth is that in every department of life there has been a tremendous advance, due to the exercise of skill, ingenuity and scientific knowledge, with which the modern war vessel has thoroughly kept pace. A moment's reflection would, of course, make it very clear to us that it would be impossible to build war vessels such as we now possess unless there had been a corresponding development in every other manufacturing industry. Governor Roosevelt, when Assistant Secretary of the Navy, touched upon a very important matter connected with this subject in discussing what was known as the "Personnel Bill." In comparing the development of naval science to the point where it became necessary for every officer in the navy to be an engineer, so that it is necessary for the modern admiral to know many things of which our great Farragut, for example, was ignorant, he said that it would, of course, require vastly greater skill to handle the complicated mechanism which the modern war vessel is, than one of the old ones, but that, just as we had always been able to produce competent men to handle the less complicated vessels of former times, so without doubt we would get competent men to handle those of to-day. He had learned the fact that the modern warship is a vast engine, and to be properly controlled must be handled by engineers. Congress has in the Personnel Bill provided and directed that, as soon as we can make the necessary arrangements, every officer in the navy charged with the handling of a vessel shall be a trained engineer, and therefore we may be sure that however complicated and delicate the organisms of the machine become, we shall have officers who, by education and experience, are fitted to properly care for the valuable and delicate machines entrusted to them.

I have had a part in two wars, in both of which the navy played an important part and became dear to the people, and I have also passed through the intervening interval, during much of which the navy seemed to be entirely forgotten. I sincerely trust that, as the late war showed we know not only how to build good ships, but also to make them go and to fight them, our fellow-citizens in civil life will see to it that the navy is maintained in a state of the highest efficiency, both as to personnel and material, ever ready for efficient use when needed. In this work, which on both sides is a matter for engineers, this Institute has a vital interest, and I trust that, just as your influence has for seventy-five years been on the side of the general advancement of engineering in the mechanic arts, so it will be on the side of their advancement in the navy.

Anniversary Sermon.

DELIVERED ON SUNDAY, FEBRUARY 5, 1899, IN THE TABERNACLE PRESBYTERIAN CHURCH, THIRTY-SEVENTH AND CHESTNUT STREETS.

By Rev. Dr. Henry C. McCook.

A PROLOGUE.

The honor of the invitation to deliver this sermon was doubtless due to the preacher's position as a naturalist and an officer in two sister scientific societies, the American Entomological Society and the Academy of Natural Sciences. It is probable that no one of those who were pleased to extend the invitation thought or even knew that he had any nearer sympathy with the Franklin Institute. Yet in point of fact he began life as a mechanic. Though intended for one of the learned professions, he conceived the idea of learning a trade "to fall back upon," and so entered a printing office and acquired the "art preservative" of all arts. He can therefore claim to be a fellow-craftsman with that distinguished mechanic, statesman, patriot and philosopher after whom the Franklin Institute is named. As such your speaker indulges in the hope that he is somewhat better qualified to appreciate the work which this organization has wrought.

HENRY C. McCOOK.

This discourse is a sermon, not a historic sketch. Its aim and scope are limited by this fact, and the honor which was done me by the invitation to preach this seventy-fifth anniversary discourse was accepted with that understanding. Yet it is fitting that some mention be made of the character and service of that noble institution which was organized seventy-five years ago this day.

The main purpose of the Franklin Institute is to foster manufactures and the mechanic arts. Its founders did not make the mistake common in this day of discriminating between the manufacturer and the mechanic. To them the manufacturer was the mechanic; not simply the capitalist who controls the product of mills and of human hands, but the man who with his hands works out the products.

Its influence upon the manufacturing interests of Philadelphia cannot be estimated. It has continually reacted upon the character of the young mechanics, machinists and shop owners of the city, elevating them and thus increasing their value to the community. No factor within the city limits has had more to do in giving Philadelphia its proud position as the first manufacturing city of the country than the Franklin Institute. As much, perhaps, as any other organization, it has created that spirit among the artisans of Philadelphia which has prompted them to seek the intelligent and honorable independence of a separate home, and thus has given our city its worthiest title—the "City of Homes." The early establishment of its drawing school has been the means of creating a large class of superior artisans, who have been armed with the ability to do the best work and to rise into higher and the highest stations as architects, designers, inventors, practical machinists and master mechanics. The Franklin Institute has demonstrated by numerous examples the fact that graphics in the schools is gold in the shops.

The democratic character of this institution has been one of its most marked and excellent characteristics. Any mechanic or any person seeking to improve himself in the mechanic arts who is of respectable character can obtain admission to all its privileges. Many institutions pick their members from what they are pleased to regard as select circles, and banish disagreeable or undesirable persons by the black-ball. Not so with the Franklin Institute. Its gates stand open to the deserving. It puts to the candidate the questions that Jefferson suggested as the only suitable ones for every national officeholder—"Is he honest? Is he capable? Is he industrious?" There is no excuse for any young man, who can answer in the affirmative these questions, remaining in ignorance of those principles of mechanic arts required to make him a superior craftsman or a master mechanic.

The Institute's exhibitions, started at an early date, had a vast influence upon the industrial community in and around Philadelphia by giving the stimulus of competition and comparison. As early as 1824, the year of its organization, it established an exhibition of American manufactures in Carpenter's Hall. We would smile in this day at the thought of such an exhibition in the modest but most venerable and historic rooms of that ancient guild. But it was "the day of small things" which, like the seed, contains within it the possibilities of a mighty future. That exhibition in Carpenter's Hall was the progenitor of the exhibition of 1874, two years preceding the Centennial, and of the famous electrical exhibition of 1884. In point of fact, we may say that it was the progenitor of the Centennial Exhibition, which did so much to develop the industries of our city and of the entire country. Indeed, the first suggestion for the Centennial Exhibition appeared in the Franklin Institute, whose petition to Councils set in play the official influences which brought about such a magnificent result.

The name and service of the Franklin Institute will be justly associated with the name of its founder, Samuel Vaughan Merrick, and that of his active associate, Prof. William H. Keating, of the University of Pennsylvania. Young Merrick's conception of such an institute sprung from a keen sense of his own need of instruction to qualify him for the duties of a master mechanic. His purpose was quickened by failure to gain admission to a small club of mechanics formed for self-improvement. The club, that, through the personal pique of an officer, black-balled an earnest and intelligent applicant, has fallen into obscurity from which it is only rescued by a discreditable association with a rejected name which will be held in imperishable honor.

Merrick entered upon his plan to form a mechanics' institute open to all youth, with a wisdom and policy equalled by his persistent zeal. "The Universe," says Balzac, "belongs to him who wills, who loves, who prays. But he must will, he must love, he must pray!" Merrick brought to his task an indomitable will, a quenchless love of his humane design, and at least that spirit of prayer which lays siege to every available agent of Providence with entreaty to fellowship in work. He prevailed; and the Franklin Institute lives and will live as a monument of his forethought and philanthropy, and an illustration of what can be accomplished by young men who devote their energies to self-improvement and to the service of their fellows.

The Sermon.

THE INSPIRED ARTIFICER.

Ex. xxxi: 3-4. "I have filled him with the Spirit of God in wisdom and in understanding and in knowledge and in all manner of workmanship to devise cunning works."

"Man," says Agassiz, "is the end toward which the animal creation has tended from the first paleozoic fishes." To the keen eye of such an observer suggestions of the coming man are seen all along the pathway of the development of animal life. The palm-like mandible of the ant, the fin of the fish, the flipper of the whale, the paw of the beast; the more humanlike hand of the ape—all point forward to that organ which differences man so widely from the creatures beneath him. Man is the only creature who carries a perfected hand, with the thumb opposed not only to the first finger, but to the tips of every finger. It is because of this that he can hold the pencil, wield the pen, the chisel, the brush and that multitude of tools which puts the handiworks of humanity immeasurably above the structures of all other earthly creatures.

It is to the hand that man owes his supremacy. He is a manufacturer—one who makes with the hand, as the word signifies. From this characteristic his loftiest power and place have been developed. His naked body, his weak physical power as compared with many other animals, the slow maturity of his offspring, to say nothing of other characteristics, would have exposed him to destruction in the struggle for life. But God gave the brain to devise and the hand to wield a tool. The possibility of all the manufacturing and mechanic arts lay within that tool-holding hand. In that sign he conquered the wilderness, the sea, the forest and had dominion over all creatures. In the early records of our race in the Book of Genesis we see that the development of civilization depended upon that gift. The sword song of Lamech reveals the potency that came in the chase and in war by the invention of a superior weapon. It is the same fact on a narrower and primitive plane as that which faces us to-day in the armaments of nations.

In the same book (Gen. iv: 22) we read of Tubal-Cain as "the instructor of every artificer in brass and iron." He was a sort of embodied Franklin Institute, performing like beneficent functions far back in the morning twilight of the race. That record marks the beginning of human progress in those accessories of life which distinguish our higher civilization.

Is anyone disposed to belittle the mechanic's handicraft and the mechanic himself? Let him know that the orbit of man's greatness on this globe lies within his power of handicraftmanship! Because he is a maker, a manufacturer, a man with a hand to wield implements of construction, therefore he is predominant among his fellow-tenants of the globe.

I.

Do you ask the origin of this superiority? Our text gives answer. It is a divine gift. Bezaleel, the mechanic, was inspired by the Spirit of God for the invention and the practice of mechanic arts. Theologians are chary in the use of that word "inspired." But the Bible is very bold. The Spirit of God will not be limited in his operations by the narrow conceptions of men. Bezaleel, the mechanic, was a God-inspired man. Notice how wide is the sweep of our text: "I have filled him (Bezaleel) with the Spirit of God in understanding and in knowledge, and in all manner of workmanship, to devise cunning works."

There are various kinds of inspiration. Doubtless, the highest is that which we commonly attach to the word, viz.: a gift to one into whom the Holy Spirit has breathed the impulse and the information to declare a spiritual truth with the authority of God Himself. But our text and its connection show that in what we are pleased to regard the lower plane of human activity God also breathes into men those gifts which make them helpers of humanity. There are divers sorts of inspired men. The prophet was inspired for the chief service of humanity. Rulers and great leaders of men, like Moses and David and Cyrus, are called inspired men. In precisely the same language the mechanic, the artificer, the inventor and the instructor in mechanic arts is declared to be an inspired man.

Solomon, in the Book of Proverbs (viii: 12), personifies the Divine Wisdom in a series of striking sayings. The holy apostle deems it no irreverence to characterize our Lord Jesus Christ as the personified "Wisdom of God," who, as St. John says, "was in the beginning with God and without Him was not anything made that was made." This saying seems like an echo of the proverbialist's words, "When He prepared the Heavens, I was there; when He set a compass [a horizon] on the face of the depth, when He established the clouds above, when He strengthened the foundations of the deep."

Now, note this: In the same chapter (v. 12) it is declared, "I, Wisdom, dwell with prudence and find out *the knowledge of witty inventions.*" There is nothing new in these words written in the oldest records of the human family, with which most of us have been familiar since childhood. Yet how few of us have permitted our minds to follow what seems to be the daring flight of the Spirit of God, and to regard the "witty inventions" of all the ages of the past, and notably of our own age, as the result of that indwelling Spirit of Wisdom which possessed and inspired the men of old, and which is incarnate in the life and Kingdom of our Lord Jesus Christ! It is because of our unwillingness to look at the facts as God puts them, and of our inability to do so on account of the limitations which our man-made systems have prescribed, that such defective thinking has fastened itself upon the Church.

The deep religiousness of this view appears when we once begin to dig beneath the surface of things. For example, why should we not expect a close association between all that is best in the religious nature of man and those mechanical arts and handicrafts which are and ever have been inalienable from man's advancement to the highest degree of prosperity and civilization?

(1) The whole universe of God is a mechanism. The astronomer knows that the very remotest regions which man's thought can penetrate show the presence of order and law. The universe with its systems of worlds is moved with more than the precision of man's most perfect machinery. So unbroken is the harmony of movement among the orbs of space that the familiar phrase " the music of the spheres " is rather a statement of a sublime fact than a beautiful figure of speech. The very atoms of which the universe is created share this characteristic. Prof. Clark Maxwell, the physicist, one of the profoundest intellects of modern times, declared that "atoms have all the characteristics of a manufactured article." It follows that this world, the solar orbs, the starry systems, are but assemblages and combinations and series of objects which have been wrought out by an infinite mechanical mind with infinite mechanical skill and power. Universe is a workshop. The planets are world-ships in the countless fleets of systems sailing through the illimitable ocean of universal space. God is an architect; God is a builder; God is a geometer; God is a mathematician. His works are not, indeed, " buildings made with hands," and in strict propriety we might hesitate to speak of Him as a "manufacturer," yet in the poverty of our speech we have no better word. When we remember how the Scriptures have ventured to use a like figure and speak of the " right hand " of God, and of the "hand" that holds his children and upholds all things, we may even dare to close our climax with the assertion that God is a manufacturer! Certainly the highest objective expression of mechanic arts is found in the works of creation.

(2) It is always interesting to trace a correspondence between the laws and characteristics of nature and the fundamental principles of revealed religion. When we find these, it confirms our belief that they are products of one mind. He who built the worlds created man. He who

created the human mind inspired the Holy Scriptures which teach the highest religion known to mankind. He who inspired the skill to work inspired the law which sanctions and restricts the periods of labor. Thus we find a striking harmony between the laws imposed upon the material on which and with which men work, and the Sabbath law which conditions human labor and upon which Christian devotion mainly pivots.

Machinists generally believe that all machines require or at least are better and more enduring if given a period of rest. The atoms seem to readjust themselves and the material recurs to its primitive and normal resisting capacity. "It is an old adage," writes General Agent Wm. J. Latta, of the Pennsylvania Railroad, "that machinery needs a rest as well as human mechanism. One's razor shaves better after a few days' idleness, because thereby the temper of the steel is improved. Locomotives are supposed to be built to run so many miles, whether continuously or intermittently. But it has never been controverted that a few days in the shop to clean out the journals, face up the valves and calk the flues is more frequently necessary to a 'first-in, first-out engine' than to one having a regular six or four days' run."

Through the politeness of Mr. John H. Converse, of the Baldwin Locomotive Works, I have received a statement made by Mr. Wille, of the Department of Tests, which is almost startling in its character and far-reaching in its inferences. He says: "The fact that metals are injured by the repeated application of stresses without intervals of rest is so well recognized that the terms 'fatigue,' 'limit of endurance,' etc., are extensively used in metallurgical nomenclature. A certain grade of steel, which has an absolute tensile strength of 80,000 pounds per square inch and which will not be permanently deformed unless subjected to a stress greater than 40,000 pounds per square inch, will rupture in service by the repeated application of a stress of about 20,000 pounds per square inch. If, however, *the material is given intervals of rest*, or if the stress does not exceed about 16,000 pounds per square inch, the material will withstand an infinite number of applications without failure. That *the physical properties of steel are improved by periods of rest is proved.*"

It is remarkable to find a law which we have always fancied to be applicable to rational man alone thus impressed upon the essential nature of insensate matter. Yet, why should it not be so? Man is a child of Nature; that is, he is a child of God. He is a product of the great creative week whose record in Genesis gives us the birthday of the Sabbath. Every successive era, or age, or creative day is there distinctly marked by a cessation of energy. Every creative day is followed by its evening of repose, until the divine Sabbath of the Creator is ushered in with the creation of man. Thus the Divine Mechanician seems to have impressed upon the nature of the materials with which mechanics work that law of periodic rest which is a pivotal command of our holy religion.

II.

THE SACRED USES OF THE MECHANIC ARTS.

We shall lose the significance of our text if we do not note in the next place the Purpose of this Inspiration of Bezaleel to the work of the artificer. His special office was to build the Sanctuary of Jehovah. He was to erect and embellish that tabernacle-temple wherein the Spirit of the Almighty dwelt to guide his people during their long wilderness journey. It is the type for all coming time of the presence of God, and the Divine purpose to lead to a higher and better life here, and to the celestial Canaan hereafter, the children whom he has made. This is and ought to be the sacred purpose of the mechanical arts. Every gift of God to man is intended to develop his better nature, and to make the world a better world to dwell in.

The Franklin Institute has not been derelict in this duty. It has contributed to the development of manhood. Take an example. A young bricklayer entered the institution, and, while working with his hands by day, availed himself of the privileges of the drawing-room, the library and other helpful facilities. As he acquired information and developed ability for construction, his purpose to become an architect was matured. In time he entered upon his profession. The days passed by. Men gathered to commemorate the opening of that beautiful Grecian temple of philanthropy and learning known as Girard College. The young bricklayer was its architect! Go to the Capital City of your country. Stand on Pennsylvania Avenue and look along it until your vision is stopped by the massive wings and swelling dome of that legislative temple under which meets the Congress of the United States. The young bricklayer, a student of the Franklin Institute, was its architect. The skill which enabled Thomas U. Walter to create these monuments of the mechanical arts was developed in the working rooms of the Franklin Institute. This is a single illustration. Numbers might be quoted.

The Franklin Institute has been a maker of men. It believes thoroughly the lines of Goldsmith:

> "Ill fares the land, to hast'ning ills a prey,
> Where wealth accumulates and men decay!"

It undertakes the exalted office of preserving men from decaying in the vast accumulations of wealth in our country. It acts upon the divine and statesmanlike theory of political economy that the wisest and the best form of philanthropy is to help men to help themselves. It puts a ladder to their feet, within their reach and aid, and encourages them to climb. If they are content to remain at the foot of the ladder, there is no power that can elevate them. If they have already experienced the power of an intellectual resurrection, they will avail themselves of the offered help. True manhood must issue from the mind. But the mind needs an exterior and superior voice to awaken it to new and higher endeavor. Aspirations must be planted from the outside, and when they are in bloom, the wisest offer of self-help will assure their elevation in life.

> "'Tis God gives skill;
> But not without man's hands. He could not make
> Antonio Stradivari's violins without Antonio."

The Franklin Institute is both the animating voice quickening loftier aspirations within the minds of young artisans, and the helping hand that points to and sustains upon the upward path of attainment.

Men of wealth in America, and largely so in Great Britain, are the result of favoring conditions in an environment not hostile, but helpful to progress and prosperity. Men like Baldwin, Harrison, Carnegie, Bell, Edison, and hundreds of others, are the product of just such influences as the Franklin Institute has made possible to every mechanic. This fact is a saving element in the community. It shows that poverty is no insuperable barrier to position; that there is no such thing as a favored "class" in this country save in the distorted imagination; that honesty, ability and industry, fostered by the public institutions that everywhere reach out their hands of help, need "know no such word as 'fail.'" Here, in our Republic, certainly in Philadelphia, the "masses" are favored; and if in any sense "classes" appear, it is because they rise up out of and are differentiated from the masses by more intelligent purpose, more persistent industry and zeal associated with those natural gifts by which the Creator distinguishes men from their fellows.

Again, physical sciences and arts erect a basis of union between nations. They have the gracious office of the peacemaker, and therefore share the beatitude of those who are called the children of God. The nations have been bound into one community by the inventor and the mechanic. Fleets of steamships unite the islands of the sea with the continents, and the continents with one another. On the continents themselves nations are united by railways. As they come in closer contact with one another the brotherhood of humanity becomes more manifest. The kinship of commerce, religion, science, art, industry and literature is recognized, and soothes ethnic prejudices and silences the hostilities of ancient hereditary feuds. It is true that the clash of material interests is likely to produce frictions; nevertheless the prevailing tendency of widely diffused traffic in the products of manufacturing hands is to bring about a state of peace. Peace brings prosperity. Peaceful competition has in it richer fruitage than can possibly be gleaned from the blighted fields of war. Rudyard Kipling has given striking utterance to this thought in his "Ode to the Deep-Sea Cables:"

"They have wakened the Timeless Things; they have killed their father Time;
Joining hands in the gloom a league from the lost of the sun.
Hush! Men talk to-day o'er the waste of the ultimate slime,
And a new Word runs between, whispering: 'Let us be one!'"

It needs no prophetic vision to stand in this City of Brotherly Love, which by a happy coincidence is the city of the mechanical arts as well, and, looking westward toward the Alaskan peninsula, discern the time when railways shall reach the border of Behring Sea. From the Alaskan shores vast ferries, to connect with Siberian railroads, shall carry to and fro the products of America and of the continents of Asia, Africa and Europe. Looking still further into the coming century, we may see ships of the air speeding to and fro in the atmospheric ocean, bearing passengers and products as to-day they are carried in our steamships. The Apostle John from Patmos, his island of exile, beheld in prophetic vision the day when there "shall be no more sea." It is a bold and magnificent figure of speech. We have seen it measurably made real in our generation. During the life of the Franklin Institute the oceans have been bridged with ten thousand hulls, and the continents united by cable communication. There are some of the junior associates of the Institute who will live to see the wider fulfilment of the Apostle's metaphor, when the atmosphere, untroubled by mountains and rivers and lakes and ocean and seas—the atmosphere which binds continents together as the land of a single continent binds the nations thereof, shall be the common highway of the human race

"From Greenland's icy mountains
To India's coral strand!"

We need not pursue this attractive theme. The point here to emphasize is that these divine gifts and powers involve high responsibility. Your preacher pleads that the world's workshops and workers and all their products should be consecrated to the honor of God and the highest interests of mankind. Every workman should deem himself an inspired Bezaleel to labor upon the Sanctuary of a Redeemed Humanity. Every work of human hands should be reckoned as a sacred work. George Herbert truly says:

"To sweep a room as for God's law
Makes that and the action fine."

Longfellow, in his "Christus," utters a similar sentiment:

"The architect
Built his great heart into those sculptured stones,
And with him toiled his children, and their lives
Were builded, with his own, into the walls,
As offerings unto God."

Perhaps the highest product of the mechanical arts is a great steamship. There it floats upon ocean, a microcosm, a little world in itself! It embodies the finest and furthest outreachings of the inspirations of the human mind in shaping inanimate matter and regulating physical forces. When of old the prophet rescued a lost hatchet from the stream into which it had fallen and restored it, a priceless implement then, to the hands of the student who had lost it, it is recorded as a miraculous thing that "the iron did swim." Lo! our miracle is a common fact. The iron swims, and swimming bears with it to all the ports of earth the proof that modern mechanical art lies within the orbit of the miracles of ancient time. "The wheel has come full circle round." Look at the steamship's ribs of iron bent into seemly shape and riveted and seamed until it floats over ocean like a bird, proudly cutting through the waves and hurling the billows from its bow. Look at its engines, marvels of human skill and of human power over the latent forces within a drop of water. See its electrical lights flashing through cabins and over decks. Note the modern appliances that constitute it a miniature city of civilization, a floating ark of the mechanical arts. It struggles victoriously with the waters; it fights triumphantly with the wind; it overcomes the death that lies within the storms of ocean, and fulfils its beneficent mission to bind the nations into one. The discipline of its crew shows the sway of regulating and regulated mind. If it be a ship of war, it carries latent judgment in its battery, and, armed with the power to vindicate and punish wrong, walks the waters bearing the sword of justice ordained against the evil-doer. "Take it all in all," says Ruskin, "a ship of the line is the most honorable thing that man as a gregarious animal has produced."

Yet we will join with the good poet Whittier in praying that God may speed the day when our ships shall be only the carriers of blessings, and our war vessels shall be messengers of peace, and run to and fro upon the waters of the ocean with no more warlike function than that of the river police boats that plough the quiet waters of the Schuylkill and the Delaware:

> "Speed on the ship! But let her bear
> No merchandise of sin,
> No groaning cargo of despair
> Her roomy hold within;
> No Lethean drug for Eastern lands,
> No poison draught for ours;
> But honest fruits of toiling hands
> And Nature's sun and showers."
>
> —*Whittier*, "The Ship-Builders."

Religion owes a great debt to the mechanical arts as they, on the other hand, are debtor to religion. In truth they are handmaids. The progress of religion in modern days has been along lines of mechanical development. Home missions in America have been largely a question of transportation. The distribution of the Gospel, the establishment of churches, Sunday-schools and educational institutions have been along the lines of railways. The work of foreign missionaries would have been impossible without the ships that have carried our devoted toilers for Christ and humanity to the nations of heathendom. As the hand of industry has opened up the country, the Church has followed. And the reverse is true, for oftentimes the Church has been the pioneer and industry has followed in her wake.

One of the happiest spectacles that our favored land affords is that of the vast plains of the West and Northwest occupied by a prosperous populace from whose homes in every village and town and city and countryside one may see the humble sanctuary raising its bell-tower, or its spire pointing like a finger-board toward Heaven, saying: "This is the way; walk ye in it!" But what made it possible for human beings to occupy successfully these great plains? Mowing machines, ploughing machines, agricultural implements, the creations of mechanical invention, the products of the mechanical arts! These are the weapons by which the vanguard of the Army of Civilization has conquered the imperial domain so long known as "The Great American Desert." These are the implements by which the path has been cleared along which the Church, the School, the Press and the Home have advanced from the Atlantic to the Pacific coast, and the solitary places have been made glad and the wilderness of the Far West has been made to blossom as the rose.

"And the smith his iron measures hammered to the anvil's chime,
Thanking God whose boundless wisdom makes the flowers of poesy bloom
In the forge's dust and cinders, in the tissues of the loom."
—*Longfellow.*

The ancients represented Jove as grasping the lightnings. That was the highest symbol of divine power. To-day man stands as did the Jovean divinity with the lightnings in his hand. They are under his power and control. They are the vehicles and motors of Language and Light and Locomotion to the men of modern days. The ancients represented Vulcan, the lame Lemnian, as one of the mightiest of divinities, whose forge and hammer and anvil were symbols of a divine power. They devised, perhaps, better than they knew; or, if they understood, then they had a wisdom from which moderns may well learn a lesson. Man stands to-day with power over all the forces of Nature. It is his heritage, it is his destiny—it is a divine destiny, and he must go forth to its achievement. When God made man he gave him dominion over all the earth. Nothing was excepted. He holds the lightnings as in the hand of God and for God, and he wields the hammer in all industrial pursuits with the arm of a divinity. God has truly inspired him and gifted him to the work of redeeming mankind from all that is low and sinful. It is his to lift men out of their unworthy selves, and place the hand of humanity within the hand of the Deity that God and man may together possess the earth, God in man and man in God, God with man and man for God. In this happy alliance the inspired artificer shall find his highest vocation, his worthiest function, his loftiest destiny. Thus, when life ends man shall pass to God in the Eternal Heavens, and there shall be revealed to him the mysteries of the mechanism of the Universe and the Holy Mysteries of Spiritual Communion with God, Who sitteth upon the Throne, and of the Lamb forever and ever.

The sound of the loom and of the hammer, of the plane and the saw, of the trowel and the axe, may well harmonize, in the presence of the Highest, with the music of the Celestial Choirs:

" As great Pythagoras of yore,
Standing beside the blacksmith's door,
And hearing the hammers, as they smote
The anvils with a different note,
Stole from the varying tones that hung
Vibrant on every iron tongue,
The secret of the sounding wire,
And formed the seven-chorded lyre."

—*Longfellow.*

The harp is the symbol of the Celestial praise. Surely the hands that in God's mundane workshop have been inspired to form from mute and insensate matter that instrument of praise, and all others of which it is the type, shall be given new cunning and skill to adorn the Sanctuary of the Almighty in the highest Heavens. If there is a place for the Inspired Artificer here, there will be place for him yonder, and a sphere for the development and exercise of his gifts. God does not change. Man will not change, except for the better, and human betterment has ever been wrought by invention and industry.

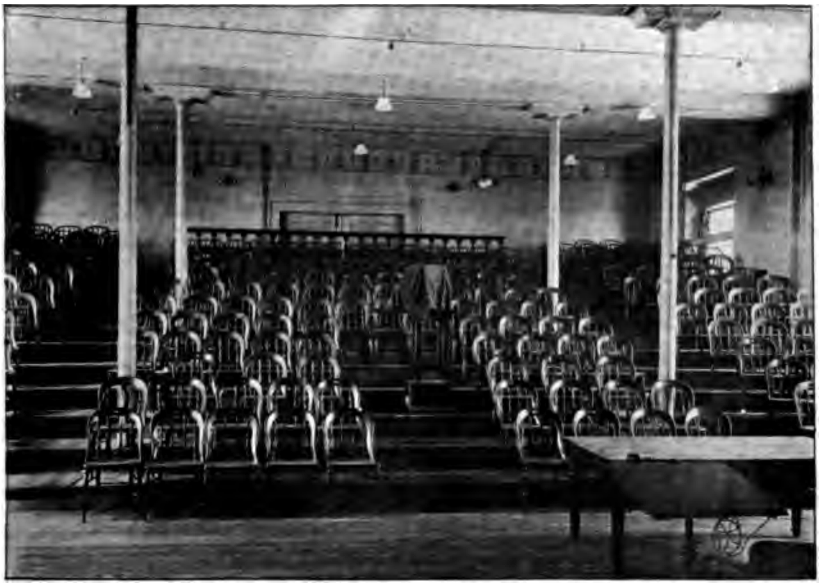
The roar and jangle and pitiful wails of war have not been heard in Heaven. No room for war-implements in the workshops of Paradise! Peace—eternal Peace shall enfold the celestials. And in the Temple and House of God, and in the City of God, the New Jerusalem, and in that Better Country where

"Fragrant flowers immortal bloom,
And joys supreme are given,"

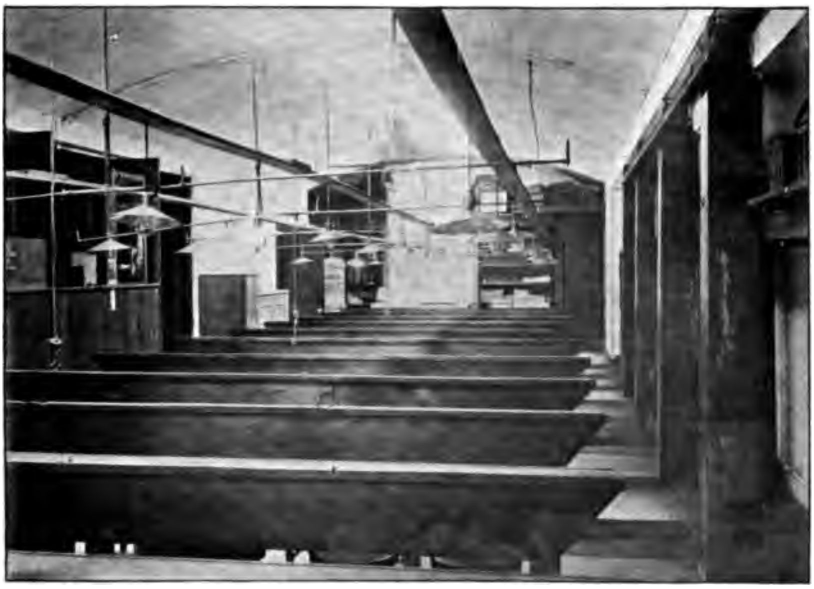
both reason and religion inspire the hope that the beautiful arts of Peace shall give play to the thoughts and employment to the hands of man, the redeemed and immortal manufacturer and mechanic. Make room in Heaven—yes, God will make room for the Inspired Artificer!

View of the Reading-Room.

The Library—View of the Bookstack.



View of the Lecture-Room.



A Class-Room in the Drawing School.

Appendix.

Although not bearing directly upon the seventy-fifth anniversary celebration, there are certain matters of interest growing out of the relations of the Institute to the National Export Exposition that may appropriately be referred to in this volume.

THE BUREAU OF AWARDS.—At the stated meeting of the Board of Managers, held Wednesday, September 13, 1899, the President announced that it was the wish of the management of the National Export Exposition that the Franklin Institute should undertake the task of investigating the exhibits and the making of awards for merit, in conformity with the rules of the Institute.

The Board of Managers, on behalf of the Institute, accepted the responsibility, and referred the subject to the Committee on Exhibitions, with full authority to act in the premises.

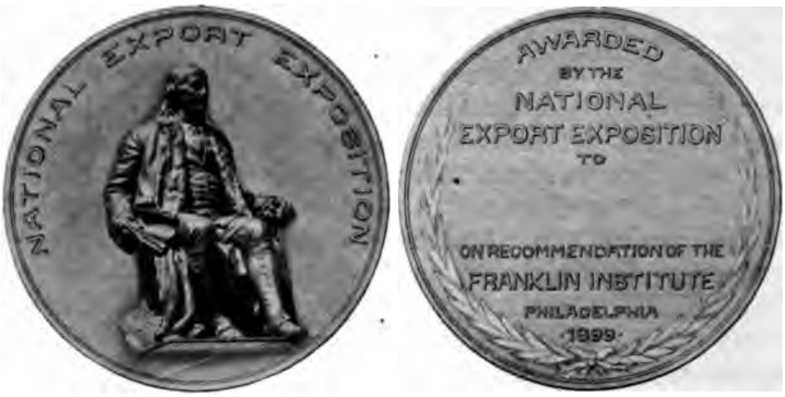
The Secretary of the Institute was charged with the duty of making a preliminary classification of the exhibits and of drafting letter to exhibitors describing the manner in which the Committee purposed undertaking the examination of exhibits, and the kind and significance of the awards to be made in deserving cases, and inviting exhibitors to avail themselves of the opportunity to submit their exhibits to the Judges to be appointed.

HENRY HOWSON.

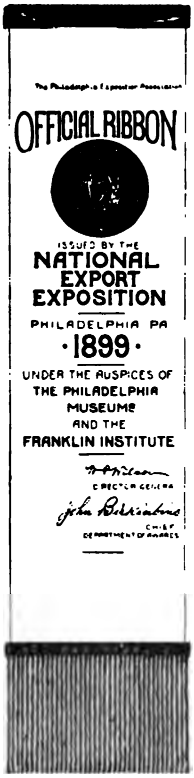
These announcements called forth favorable responses from practically all the exhibitors.

Following this, the Committee proceeded to appoint judges in each group contained in the classification, as finally adopted.

[Full details of these matters—the classification, personnel of the judges of each group, etc.—will be found in the official report of the Exposition.]

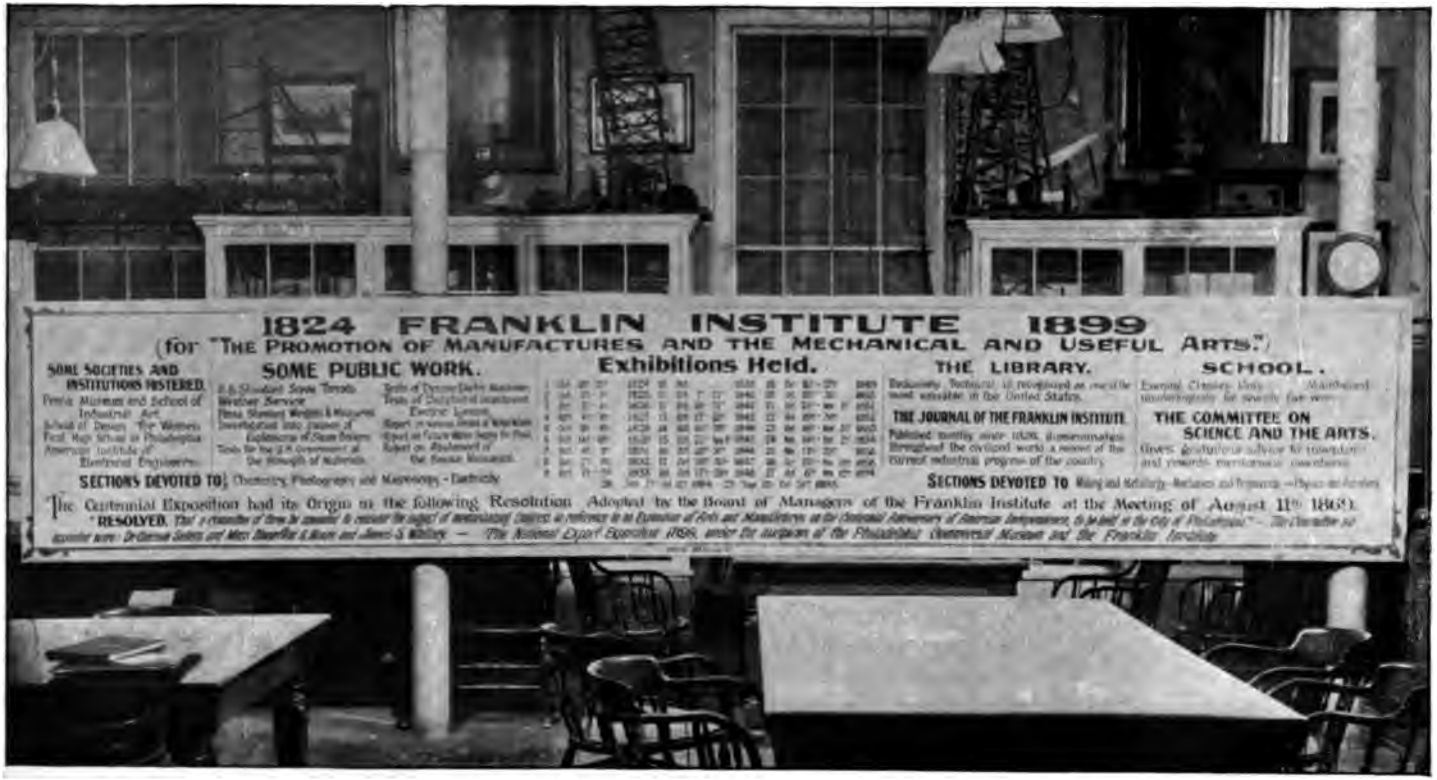

NATIONAL EXPORT EXPOSITION
AWARDED BY THE NATIONAL EXPORT EXPOSITION TO
ON RECOMMENDATION OF THE FRANKLIN INSTITUTE PHILADELPHIA 1899

The body of judges selected in the manner just described constituted what was known as the "Bureau of Awards," to which the reports of the judges of the several groups were, in the first place, submitted for approval.


The Philadelphia Exposition Association
OFFICIAL RIBBON
ISSUED BY THE
NATIONAL EXPORT EXPOSITION
PHILADELPHIA PA
·1899·
UNDER THE AUSPICES OF THE PHILADELPHIA MUSEUMS AND THE FRANKLIN INSTITUTE
DIRECTOR GENERAL
CHIEF DEPARTMENT OF AWARDS

In the matter of appeals from the decision of the Bureau of Awards, the Board of Managers subsequently decided that "the Committee on Exhibitions of the Board, in conjunction with the officers of the Institute, constitute an Executive Committee, to examine and finally act upon the reports of the judges, and that all disputed points that cannot be settled by this Committee be reported to the Board of Managers for final adjudication."

At the meeting of the Board of Managers, held Wednesday, November 27, 1899, called specially for the consideration of exposition business, Mr. Henry Howson, Chairman of the Committee on Exhibitions, made a brief report of the work accomplished by the Bureau of Awards, and submitted designs for the medal which it was in-



1824 FRANKLIN INSTITUTE 1899

(for "The Promotion of Manufactures and the Mechanical and Useful Arts.")

SOME SOCIETIES AND INSTITUTIONS FOSTERED.

SOME PUBLIC WORK.

Exhibitions Held.

THE LIBRARY.

SCHOOL.

THE JOURNAL OF THE FRANKLIN INSTITUTE.

THE COMMITTEE ON SCIENCE AND THE ARTS.

SECTIONS DEVOTED TO

SECTIONS DEVOTED TO

The Centennial Exposition had its Origin in the following Resolution Adopted by the Board of Managers of the Franklin Institute at the Meeting of August 11th 1869.

"RESOLVED.

Chart Exhibited in the Reception Room of the Franklin Institute, at the National Export Exposition, September 14–November 30, 1899.

tended to be granted to those found entitled to the distinction; also, a sketch of the diploma to be issued in connection therewith, and of an official ribbon containing a brief statement of the fact that an award had been made, and of which exhibitors could obtain copies on proper application.

[Pictures of these several emblems are shown herewith.]

The Committee was given full authority to proceed in the premises, the designs submitted having been approved.

In conclusion of the foregoing memorial tributes there is hereto appended the opening address of welcome by Director-General Wilson, which should have been printed in connection with the events of opening night, Monday, October 2, 1899, but was unavoidably omitted from its proper place; also, a list of institutions and prominent persons from whom letters of greeting were received.

Address of Welcome.

DELIVERED IN CONVENTION HALL OF THE EXPOSITION AT THE OPENING CEREMONIES

OF THE

SEVENTY-FIFTH ANNIVERSARY OF THE FRANKLIN INSTITUTE.

By Dr. William P. Wilson, Director-General.

Members of the Franklin Institute, Ladies and Gentlemen:

There are several reasons why it is particularly appropriate for the Director-General of this exposition to say a word before this distinguished body of gentlemen affiliated with the Franklin Institute. And, first of all, the Franklin Institute has taken a very leading part, stood shoulder to shoulder with all other workers in creating this exposition. In fact, the Franklin Institute and the Philadelphia Commercial Museum have brought about this exposition under their joint auspices.

While the Franklin Institute is over seventy years old and has conducted many successful exhibitions in science and art, the Philadelphia Commercial Museum is scarcely five years old and is experiencing its first work in this direction. The great help and guidance of the Franklin Institute in this work, therefore, goes without saying. It has been the life and practice of the Franklin Institute to encourage all useful inventions and apply them to manufacturing interests and to the arts of life.

As the main object of the Philadelphia Commercial Museum is the stimulation of all manufacturing interests and the general increase in commerce between this and other countries, what closer bonds could possibly exist between two institutions than between the Commercial Museum of Philadelphia and the Franklin Institute, the former bringing individuals from all parts of the world together to stimulate closer commercial relationship, and the latter making practical application of all modern inventions for similar purposes?

The Institute has made a most enviable reputation for itself in the course of its long career. I suppose there are very few societies which could show a more splendid record for seventy-five years of hard work than this body which has grown up in Philadelphia and may be considered as peculiarly a Philadelphia institution.

WILLIAM P. WILSON.

In the list of the estimable advantages which we enjoy as a nation, not the least is our ability for applying science to the mechanical arts to the nation's benefit, and indeed to the universal benefit of mankind. And this has been peculiarly the province of the Franklin Institute. The application of science to the mechanic arts has greatly furthered commerce in navigation, and has favored the production of almost everything which serves the necessities or luxuries of mankind, and the work of the Franklin Institute is laudatory in the highest degree.

It gives us great pleasure, therefore, to especially welcome the delegates and members of the Franklin Institute at this opening meeting in a series which, I prophesy, will be most profitable to the members and the delegates of the Franklin Institute, but still more to the community and the country at large.

Letters of Greeting

were received from the following:

The President of the United States.

The Honorable, the Secretary of War.

His Honor, Samuel H. Ashbridge, Mayor of the city of Philadelphia.

His Honor, A. Van Wyck, Mayor of the city of New York.

Hon. Abram S. Hewitt, Ex-Mayor of the city of New York.

Hon. James Rankin Young, H.R. (Committee on the Merchant Marine and Fisheries).

Hon. Frederick Fraley, Philadelphia (President American Philosophical Society and of the National Board of Trade).

American Academy of Arts and Sciences (Prof. T. C. Mendenhall, Delegate).
American Academy of Political and Social Science.
American Society of Civil Engineers.
American Geographical Society.
British Iron and Steel Institute.
The Pennsylvania Academy of the Fine Arts.
Philadelphia Normal School for Girls.
Philadelphia College of Physicians.
Pratt Institute.
Massachusetts Institute of Technology.
Pennsylvania State College.
Haverford College.
Bowdoin College.
Cornell University.
Columbia University.
Columbian University.
Harvard University.
University of Wisconsin.
University of Illinois.
University of Iowa.
University of Missouri.
University of Maine.
University of Michigan.
University of Nebraska.
University of Toronto.
University of Wyoming.

Maryland Historical Society.
U. S. Geological Survey.
Lumbermen's Exchange.
Young Men's Christian Association, Central Branch, Philadelphia.
Beneficial Savings Fund Society, Philadelphia.
New England Cotton Manufacturers' Association, Boston.

Prof. Martin H. Boyè, Coopersburg, Pa.
Hon. George F. Edmunds, Philadelphia.
General Louis Wagner, Philadelphia (President Third National Bank).
J. M. Collingwood, Philadelphia (President Centennial National Bank).
Jos. S. Harris, President Philadelphia & Reading Railroad Co.
A. J. Cassatt, President Pennsylvania Railroad Co.
Prof. W. O. Atwater, Wesleyan University, Middletown, Conn.
Mr. John H. Converse, Philadelphia.
Prof. Alexander Agassiz, Newport, R. I.
Prof. W. M. Davis, Harvard University.
Mr. James M. Beck, U. S. District Attorney, Philadelphia.
Mr. Oberlin Smith, Bridgeton, N. J.
Signor G. Marconi, New York.
Dr. Henry Morton, Hoboken, N. J. (President Stevens Institute of Technology).
Mr. Wm. F. Durfee, Staten Island, N. Y.
Prof. Chas. R. Cross, Boston.
Prof. H. C. Bolton, Washington, D. C.
Prof. F. B. Crocker, New York.
Prof. Henry Willis, Philadelphia.
Prof. Albert H. Smyth, Philadelphia.
Prof. S. F. Peckham, New York.
Rear-Admiral W. T. Sampson, U. S. N.
Rear-Admiral Casey, U. S. N.
Capt. George O. Squier, U. S. N.
Mr. T. Commerford Martin, New York (Editor *Electrical World*).
A. B. Meyer, M.D., Director of the Royal Zoölogical, Anthropological and Ethnographical Museum at Dresden, Saxony.
And many others.

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